June 2004

STATUS

A REPORT ON WOMEN IN ASTRONOMY

CONTENTS

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

Jocelyn Bell Burnell is Dean of Science at Bath University, England. She looks back at the discovery of pulsars 35 years ago, in her Presidential Address of 2003 to the Royal Astronomical Society.

This article first appeared in the February 2004 issue of Astronomy and Geophysics and is reprinted here with the permission of Blackwell Publishing and the author.

Pliers, pulsars and extreme physics

By Jocelyn Bell Burnell

Thirty-five years ago, when research students joined the Cambridge Radio Astronomy Group they were presented with a set of tools. It was very nice that the Cavendish could afford to give tools to all of us, but it was also a very clear statement about what kind of work you were expected to do. In fact I spent the first two years of my PhD "in the field", in one field in particular on the Barton Road about three miles from the centre of Cambridge, at the Lords Bridge Radio Astronomy Observatory.


Photo by Bell-Burnell collection

Jocelyn Bell Burnell

In an area the equivalent of two football pitches, six of us built an array of a thousand wooden posts, 2048 copper dipoles and 120 miles of wire and cable. It operated at 81.5 MHz and took about two years to build. We built the telescope at the height of the Rhodesian copper crisis, using several tons of copper wire, and we always had nightmares that we would come out one morning to find someone had been round with wire cutters and removed the copper. It had happened to one of the subsidiary radio telescopes, but it didn't happen to this one.

I was primarily responsible for the cables and plugs. John Pilkington mass-produced antennae and feeder wire and from time to time almost got tangled up in birds nests of copper wire, and wehad some enthusiastic summer students with

Continued on page 2

Editor's Note

By Fran Bagenal

This issue of STATUS heralds a transition in the editorial team. Lisa Frattare has stepped down, Meg Urry has stepped back and Pat Knezek is chairing the CSWA. Fran Bagenal has taken over the reins, with Joannah Hinz continuing to assist. This issue contains several articles presenting results of surveys of demographics. We hope that future issues will emphasize what can be done - by individuals, employers and institutions – to improve the numbers of women and work environment in our profession of astronomy. ❖
(see photos on the back page)

Portrait of a Decade: Results from the 2003 CSWA Survey of Women in Astronomy

By Jennifer L. Hoffman and Meg Urry

In the early 1990s, the organizers of the first Women in Astronomy conference at STScI realized that although anecdotal evidence and their own experience suggested that women were underrepresented among astronomers, no statistical data existed to help them define or quantify the problem; past demographic surveys had always combined astronomy with physics or other sciences. The STScI group therefore set out to conduct the first survey of the gender distribution of astronomers at major U.S. institutions. Ethan Schreier presented their results at the Women in Astronomy conference (*Proceedings of the Conference on Women in Astronomy, 1992*; **www.stsci.edu/stsci/meetings/WiA/schreier.pdf**).

Continued on page 8

Pliers, pulsars *continued from page 1*

sledgehammers. I was spared most of the sledge-hammering but nonetheless when I left I could swing a sledge. So my first couple of years involved a lot of very heavy work in the field, or in a very cold shed, with a team of people who were very good to work with. In the rubric describing research studentships there was (and probably still is) something about acquiring skills – and don't supervisors exploit that!

We were using a technique that was novel then, called interplanetary scintillation. Basically, just as in the night sky you can see that stars twinkle and planets don't (by and large), so in the radio sky compact objects scintillate and extended objects do not. The true nature of quasars began to be appreciated in about 1963 when Martin Schmidt identified the redshift of quasar 3C48. In 1965 Tony Hewish won a large sum of money from the Science Research Council to build this radio telescope. Tony's proposal hinged on the fact that compact quasars would twinkle or scintillate whereas the rather more extended, large angular diameter radio galaxies would not, so we had a neat way of picking out the quasars.

Figure 1: Our technician Don Rolph and the four-acre telescope. One row of antennae goes behind Don's right shoulder, and another runs from the top righthand corner of the photo. Twin-wire feeder from an antenna curves down past Don's head and joins a horizontal run of twin-wire feeder. The slanting beams carry the reflector (tilted to look at the ecliptic); the reflector is made up of wire, too fine to be seen in the photo."

Interplanetary scintillation in action

Not only could we pick out the quasars, we could even get a stab at their angular diameter, because the scintillation is caused by the solar wind, the plasma that is blowing out from the Sun. That plasma is not perfectly uniform. It contains blobs or clouds which gradually expand as they move away from the Sun. If the source is sufficiently small that you see it through just one blob, or between blobs, then it will twinkle as the blobs blow across, but if it's extended and you're seeing it through several blobs then it doesn't twinkle much. When the line of sight to a quasar is well away from the Sun, you are looking through one expanded blob after another and the quasar will scintillate like fury. Closer to the Sun where the angular diameter is comparable to the blob size, you look through several blobs and the scintillation disappears. If the broad idea is correct you can watch an object through the year and see when it starts scintillating and when it stops and that, in theory, gives you a measure of the angular diameter.

And so, when I arrived in Cambridge, was presented with my tools and started building this radio telescope, I believed I was in a project to identify as many quasars as possible in the sky visible from Cambridge, and to have a stab at measuring

STATUS

Edited by
Fran Bagenal (U. of Colorado)
bagenal@colorado.edu

Associate Editors
Joannah Hinz (University of Arizona)
jhinz@as.arizona.edu
and Patricia Knezek (WIYN Observatory)
knezek@noao.edu

Contributing Editors
Meg Urry (Yale University)
meg.urry@yale.edu
and Lisa Frattare (STScI)
frattare@stsci.edu

Design by
Krista Wildt (STScI)
wildt@stsci.edu

Published by
the American Astronomical Society
2000 Florida Avenue, NW, Suite 400
Washington, DC 20009

STATUS is produced at the
Space Telescope Science Institute
3700 San Martin Drive
Baltimore, MD 21218

The STATUS newsletter is distributed to AAS members at the January and June meetings and sent to home institutions of subscribers during the week of the meeting. Contributed articles are encouraged. Deadlines for submission are October 1 and March 1, respectively.

For more information on subscribing to STATUS, submitting articles or obtaining back issues, please visit the STATUS website:
http://www.aas.org/~cswa/status

their angular diameters. And in fact, that is what my thesis was about, because by the time pulsars came along, my supervisor, Tony, advised me that it was too late to change the thesis' title. From what I now know about university systems, I think he was wrong, but as a PhD student I believed him. So the pulsars went in an appendix and I wrote a substantial thesis on the angular diameters of quasars using an interplanetary scintillation technique, all done within a three-year period.

An important factor in this story is that the scintillation, the "twinkling", is quite rapid, and if you're going to "see" twinkling you have to have a system that responds fast enough to follow the changes in brightness. So the instrument has to have a short time constant, like making a rapid exposure with a camera. If you have a short time constant you lose some of the advantages of integrating for a long time. You have problems of signal-to-noise ratio and the way you get round them is to increase the collecting area of your radio telescope. Hence the 4.5 acres of radio telescope operating with a time constant of something like a tenth of a second – a combination that had not been used before. After the two years building the radio telescope the rest of the construction team moved on to other projects and I, the research student, was left to operate the telescope. It was a very simple operation: you scanned one strip of the sky; the next morning you went out to your telescope, flipped a few switches and scanned the next strip of the sky; next morning you went out and set the telescope to scan the next strip; and so on, day after day. Exciting isn't it? Just like all PhDs!

Miles of chart paper

There weren't many computers in those days. In Cambridge there was Titan and the radio astronomy group had some time on it, but that time was used for the aperture synthesis of the One Mile Telescope results, and those of us on other projects did not have access to any computers. We used research students instead. We output our signal on paper charts, red pen over moving paper, and then we analysed the paper charts. This telescope produced 100 feet of chart paper every day and one complete scan of the sky took four days or 400 feet of paper.

One of the things you have to get used to when you start operating a radio telescope is the effect of interference and how it appears on the charts. And we very quickly identified interference – it was usually strong enough to wipe everything else out. We also got used to identifying the scintillating quasars. There were a goodly number of those – although we weren't clear we were measuring the angular diameters that well. But it was clearly a successful project. As the only student on the project it was my job to analyze those hundreds of feet of chart paper. It was quite a job just keeping up with it and my logbook has dismal statements like "now 1000 feet behind with the chart analyses" and "now 2000 feet behind with the chart analyses". In the six months that I personally operated the telescope, several miles of chart were recorded.

A scientist, particularly somebody trained in the physical sciences, has a brain that stores problems, such as things one doesn't understand. Those of us who have trained as physicists have learnt to be economical with our brains. We know that if we understand something we don't need to worry, but if there's something we don't understand, we file it somewhere. In among each 400 feet of chart paper there was occasionally a quarter inch that I did not understand. What niggled me about that quarter inch was that it didn't look like a scintillating quasar, and it didn't look like interference. It was a bit of a puzzle. A further puzzle was that it was intermittent. The first few times I saw this I noted it as a query. But by the second or third time I'd seen this funny, scruffy signal my brain cells were beginning to connect and said "I've seen this sort of signal before. I've seen this sort of signal, from this bit of the sky before, haven't I?" And then it's easy. You get out the charts from previous runs that cover that bit of sky; you spread them out all over the floor so that you can see them, and you realize that yes, you have occasionally seen a quarter inch of signal like that before from that bit of the sky.

I talked to my supervisor. One of our ideas was that it might be a particularly compact source, useful for calibration. In retrospect this was a silly idea because it didn't explain the one-sided nature of the spikes that made up the signal. But when you're struggling you don't always reconcile all the information. So we planned to make the equivalent of a photographic enlargement. We wanted this signal to take up not just a quarter inch but be spread out so that we could see the structure. What we needed to do was to run the chart paper faster, but we couldn't afford to run the chart paper at that speed for 24 hours a day – it would run out. And of course it's the research student's job to handle these sorts of things.

So I had to go out to the observatory each day at the appropriate time, switch on to high-speed recording, run it for the duration of the transit, and switch it off again. And for a month I did that. This was an intermittent source which wasn't always there every time you looked at that patch of sky, and of course it had "intermitted away" each time I went out to observe it with the high-speed recording. For a month I made high-speed recordings of receiver noise and background noise. One day I thought "Sod this!". There was a very interesting lecture in Cambridge, about ageing,

Continued on page 4

Pliers, pulsars *continued from page 3*

which clashed with the observation. I remember it vividly, partly because of where it fell in my life, but partly because it is a topic that becomes more relevant as you get older. For the first and last time I skipped going out to the observatory that day and went to the lecture; it was a very good talk. I went out to the observatory the next morning and there was the signal!

My supervisor had been getting cross as this month of non-results proceeded. "It's a flare star and it's been and gone and done it and you've missed it!" he said. So the day after the lecture I stayed out at the observatory – not daring to go back into Cambridge, and on the high speed recorder picked up a series of pulses, a weak signal that was obviously very close to the detection threshold with some of the pulses missing, but keeping phase and keeping very precise period. You could see even as the chart flowed under the pens the regularity of the blips and you could see the period was about one and-a-third seconds. As soon as the transit was over and the recorder was switched back to normal speed I took this pen recording and laid it out on the floor and with a ruler established that the period was accurately maintained at least for the length of the recording. It's very interesting, your reactions when you see this kind of thing. I had been well-trained as an undergraduate at Glasgow University and when I saw this pulse signal coming in, one half of my brain was saying "Gee whiz it's a pulsed signal", and the other half of my brain was saying "What do I do next?"

It must be man-made

We didn't make telephone calls with quite the same alacrity then, but I called up my supervisor who was teaching in an undergraduate physics laboratory. He'd probably been dealing with some twit of a Cambridge undergraduate who thought his grating had three lines per inch, and was then phoned up by his twit of a research student who says "Tony, you know that funny scruffy signal – it's a string of pulses one and-a-third seconds apart." Tony's response was: "That settles it then – it must be man-made." Now Tony was a better astrophysicist than I was at that stage. I did not realize that a period of 1.3 seconds is really rather small for a star. I did appreciate that a pulsed signal was very peculiar and I did appreciate that 1.3 seconds sounded artificial. You can imagine somebody setting a signal generator at that rate.

Tony was interested enough to come out to the observatory the next day at the appropriate time. This was an anxious moment given how low level these signals were and how infrequently we detected them; it might not have been visible that afternoon. But bless it, it performed! Tony saw with his own eyes a string of pulses coming and that they were equally spaced, and that they were equally spaced at the same period as the previous day; so there'd been no change in period over 24 hours – no surprise given what we now know of pulsars. And that's where our troubles began.

People have asked me "Was it exciting discovering the first pulsar?" No! It was scary and it was worrying. Finding subsequent ones was great, but finding the first one was not. Tony was quite convinced that there was something wrong, that it was an artificial something or other. And of course the place you start is with your own equipment. I had wired up this radio telescope and was scared that I had literally got some wires crossed, that my stupidity was about to be discovered by the combined brains of Cambridge, and I might be leaving without a PhD. Our first task was to ask a colleague and his research student with a telescope that operated at the same frequency to see if they too could pick up the signal. We used what had been the 4C radio telescope (now kitted out with an 81.5 MHz receiver) and the memory is still vivid. The signal showed first in my radio telescope, so we knew the source was there and performing. Then we moved over to stand by the chart recorders for the other radio telescope – and nothing happened. Tony and the other supervisor, Paul Scott, started walking down this very long lab saying "Now what is this signal, what's going on?" and I tagged along behind trying to keep up with them in every sense of the word. Robin Collins, the other student, had stayed behind with his chart recorders. The discussion continued: "What could show up in our radio telescope but not in yours and has these properties?" Then Robin called out "Here it is!" and we went charging back up the lab. We had miscalculated the alignment of the second radio telescope's beam, fortunately by only five minutes. If it had been half an hour perhaps we'd have gone home and not found pulsars in Cambridge.

Our radio telescope and receiver were exonerated. Whatever the signal was, it was common to the radio astronomy site, but it looked like artificial interference. Tony had looked more carefully at its right ascension, and sorted out one of the other problems. We were using an interferometer and interferometers have fringes; or in the case of radio telescopes, negative-going lobes and positive lobes. This signal not only was weak, but also it rarely stayed strong enough for long enough to appear in more than one lobe. So typically you got a short burst of it in one of the lobes within the beam, which meant that its appearance time would jitter around by about 30 seconds. So it keeps constant right ascension – funny for artificial interference. It pulses at a very rapid rate, therefore it's small. It maintains its pulse period very accurately. Each time we went to observe the thing we found it spot on – absolutely bang on – and we were able to improve the period by another few decimal places. But if something is going to maintain its pulse period very, very accurately, it has great reserves of energy and it must be big. So it's big – and it's small.

So far away

Then we started to measure the distance. This was John Pilkington's job and I can remember him tearing his hair out. Working with a transit instrument is very tricky. If anything goes wrong and you don't have everything working perfectly for the right five minutes of the day, you've lost 24 hours. And this was technically a tricky experiment to do, although it is based on a well-known radio dispersion phenomenon. If there is a thunderstorm in New Zealand with a lightning stroke, that lightning stroke generates a radio signal. It's a broadband radio signal containing many frequencies, and that signal propagates round to the antipodes, going quite far out from the Earth following lines of the magnetic field, and coming back down in Britain. As it travels that loop of magnetic field it gets dispersed, so what started off as a single sharp broadband signal in New Zealand arrives in Britain sounding like the descending tone of a whistle; a "whistler" to the radio ham. The high frequencies travel faster and arrive first, so you hear a descending note. Similarly in space, the radio signals from stars and galaxies propagate through a space containing free electrons which will disperse a radio signal. So supposing these pulses start out like the lightning stroke as a single sharp broadband signal, by the time they have travelled to Earth they will have become spread out. The amount they are spread out depends on how many electrons they have passed. If we can guess the number of electrons in interstellar space, then we can guess at the distance; that was at the heart of the measurement that John was doing. And he came up with the interesting result that this source was about 65 parsecs, or a couple of hundred light years distant, which puts it way beyond the Earth and the solar system, but within our own galaxy – out there among the stars of the Milky Way, in the constellation of Vulpecula. So, after about a month we had established that this thing kept constant right ascension, it was at that sort of distance, that it pulsed extremely accurately, and it pulsed extremely rapidly. And we weren't at all sure what it was.

There was a meeting just before Christmas 1967 which I stumbled upon. I went down to Tony's office to ask him something and, unusually, the door was shut. I knocked and a voice said "Come in." I stuck my head around the door and Tony said "Ah, Jocelyn, come in and shut the door." So I went in and shut the door. It was a discussion between Tony Hewish (my supervisor), Martin Ryle, (the head of the Group), and probably John Shakeshaft (one of the other senior members of the Group). The discussion was along the lines of "how do we publish this result?" We only had one of these things. We hadn't a clue what it was. We had begun nicknaming it "little green men," although we didn't seriously believe it was little green men, but it was as good a name as anything else. Up to then we had kept quiet about the phenomenon because we were terrified of making fools of ourselves. What if it turned out to be a thermostat in the next village or something like that? Now we had to publish.

We didn't solve the problem that night. I went home feeling very fed up. Here was I trying to get a PhD, and some silly lot of little green men had chosen my radio telescope and my frequency to signal to planet Earth. After some supper I came back into the lab because with all the special observations there was by now a backlog of 2500 feet of routine chart analyses. And just before the lab shut at 10 o'clock I was looking at a patch of sky which included Cassiopeia A, a strong radio source, at lower culmination. It is circumpolar in Britain which means that you can pick it up beautifully in the south and, 12 hours later, if you're unlucky, it is so strong you can pick it up again in the north, through the back of your radio telescope. Then it is very low on the horizon, it scintillates like fury and it is a mess. I was looking at a record that covered such an observation and indeed it was a mess. In among the mess there seemed to be one of these funny, scruffy little signals. OK, the lab is about to shut and I don't want to be locked in for the night. Previous records of that part of the sky were pulled out very quickly and strewn over the floor; and there, on two or three previous occasions was a hint of scruff in among that Lower Cas mess. This was 21 December and I was going home for Christmas next day to announce my engagement so it was important I went.

I didn't go to bed that night. At two o'clock in the morning (the time of transit) I was at the observatory, and it was extremely cold. For reasons that I never understood, when it was very cold the telescope operated at half power. And of course that night it was at half power. So I flicked switches, breathed on it and swore at it, and I got it to work at full power for five minutes. It was the right five minutes and at the right setting. In came another stream of pulses, this time at an interval of one-and-a-quarter seconds, not one-and-a-third. This was a "eureka!" moment, because we'd been through all the tests. It wasn't a fault with the equipment, it wasn't locally generated, it was something out there among the stars. Whatever it was, this was another one, in a totally different part of the sky. It nailed the LGM

Continued on page 6

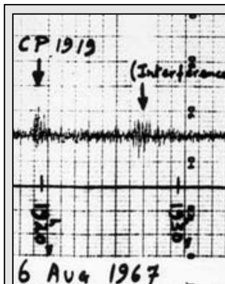


Figure 2: The first detection of the first pulsar, occupying about one-quarter inch of chart paper. About five minutes later is a short burst of low level interference. This signal has been high-pass filtered, to remove the telescope's interference pattern. (Mullard Radio Astronomy Observatory.)

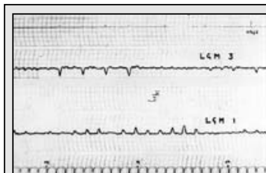


Figure 3: The bottom trace is of broadcast one-second time pips. The middle trace shows the first recording to reveal the pulsed nature of the pulsar PSR1919. The top trace is of the third pulsar discovered, PSR0834. The "LGM" notation is no longer used! (Courtesy, Mullard Radio Astronomy Observatory.)

Pliers, pulsars *continued from page 5*

theory as well, because it was highly unlikely that there would be two lots of little green men on opposite sides of the universe both deciding to signal at the same time to a rather inconspicuous star on a rather curious frequency and using a technique that was not at all intelligent. It had to be some new kind of stellar something and we'd found the first ones.

I went off on holiday and came back to the lab wearing an engagement ring. That was the stupidest thing I ever did. In those days married women did not work. They might work for "pin money" for a little time perhaps, but once the children came along everybody knew that if mothers worked the children would become delinquents. My appearance wearing an engagement ring signalled that I was exiting from professional life. Incidentally, it is interesting to notice that people were much more willing to congratulate me on my engagement than congratulate me on making a major astrophysical discovery. Society felt that in getting engaged I was doing the right thing for a young woman. In discovering pulsars, I wasn't.

And then there were four...

During my holiday Tony had very kindly kept the survey running. He'd put fresh paper in the chart recorder and fresh ink in the inkwells, and piled the charts unanalyzed on my desk. So on my return it was quite clear what I had to do. I began to think I'd had too good a holiday when after about an hour I'd found two more scruffy signals. Tony came by and said "How many more have you missed? Go back through all your old recordings." This I dutifully did, but I didn't discover any more. Over the next couple of weeks we confirmed numbers three and four. Number four was really exciting because it had a period of a quarter of a second, not one-and-a-quarter, and was stretching our understanding. It could also be, on occasion, an incredibly strong signal. It became something of a tourist attraction for other researchers and students, who would go out to the observatory at the appropriate time just to see a pen sweeping across the chart paper and banging against the end stops four times a second.

There was still the puzzle of what these things were. John Baldwin recalled an article from several years back which suggested that maybe in supernovae you could get formed things called neutron stars, and of course we also knew about white dwarfs which are fairly compact. So we composed the paper announcing the first result – and looking back on it we were mad. That first paper was based on just one hour of observation in total, but not, of course, an hour continuously. I remember a serious discussion about the title. Was it to be "Pulsating source" or "Pulsed source"? Martin Ryle called up Nature and said we'd got something exciting – hold the presses. Nature turned the paper round in about a fortnight and it appeared 35 years ago. Shortly before the paper appeared, Tony gave a seminar and announced what we had found. Fred Hoyle said at the end of the seminar "This is the first I've heard of these objects", but then immediately went on: "I don't think it's a white dwarf. I think it's a supernova remnant." It shows the calibre of the man and his astrophysical understanding that when presented with something like that, within the hour he could hit the right conclusion. Brilliant! In the paper we had been a bit ambiguous about what we had witnessed because we honestly didn't know what it was.

There was a lot of publicity following the announcement. The Press descended and when they discovered that S J Bell was young and female, they descended even faster. And that was another very interesting experience. Typically they would ask Tony Hewish about the astrophysical importance of the discovery. And then they'd turn to me and ask me what my vital statistics were or about how many boyfriends I had. I wasn't shapely enough for page three, but that was all women were for. The science correspondent of the Daily Telegraph actually named the objects. He was interviewing us one day and asked us what we were calling these things. We hadn't considered the matter, so he said: "Well, there are quasars, what about 'pulsar' for pulsating radio star?"

Now we know of about 2000. The number is going up rapidly thanks to a survey in Australia. We tend to see the ones in the nearer half of the galaxy, not the farther half because those are too faint, by and large. And we do believe that they are neutron stars – objects dreamed up by some mad theoreticians in the early 1930s shortly after the neutron was discovered! We do believe they are formed in supernovae as Fred Hoyle said, and that they are the core of the star that explodes in the supernova. Neutron stars these days are not only known as radio pulsars, they are one component in many X-ray binaries, they are gamma-ray sources, and they are probably gravitational radiation sources. We believe that what we see as the pulse period is in fact the rotation period; the magnetic axis is offset from

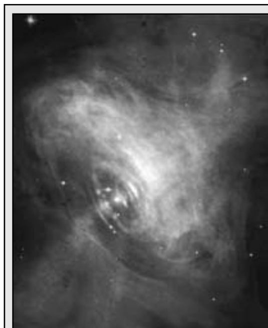


Figure 4: A Chandra and HST composite of the Crab Nebula showing X-ray and optical images superimposed. The inner ring is about one light year across. The Crab Pulsar was nearly the first pulsar to be discovered. (NASA/CXC/HST/ASU/J Hester et al.)

the rotation axis, like on Earth only more so. A radio beam comes out of the magnetic pole, and as the star spins you see one flash, or maybe two flashes per revolution. The period is so very precisely maintained because it's geared to the rotation. Getting a star rotating is hard work but once the star is spinning it is difficult to change the period. We probably only see about one pulsar in five.

So what would a neutron star be like? There's just over 1.4 solar masses jammed in a 10 km radius sphere. The gravitational field is enormous. The work put into climbing Everest on Earth is comparable to climbing 1 cm on the surface of one of these stars. Even light on the surface is bent by the gravitational field, so you can see tens of degrees over the horizon, and clocks run at half the rate they do on Earth. There's also a very strong gradient to the gravity so I wouldn't recommend going to visit a neutron star. The gravitational force on the lower part of your body is so much stronger than on the upper part that "spaghettification" and rupture take place. There's also some very interesting condensed matter physics. In brief, unlike any other kind of star that is a burning ball of gas, a neutron star is like a raw egg. It's got a solid shell on the outside and some very funny gooey liquids on the inside. More technically, the shell is believed to be an iron-56 polymer with a Young's modulus about 10^6 times that of steel. The very strong magnetic field – about 10^8 T – makes the atoms in the star aspherical. The iron atoms lock together like tent poles, producing polymers. The polymers stick together and are incredibly strong. Inside the crust is a region rich in neutrons. Elements that are radioactive here on Earth cannot decay in that regime, basically because - decay is prevented. Go in a little bit farther and inverse - decay takes place, so protons and electrons merge to give yet more neutrons and it gets even more neutron rich. Inside that is a layer of neutron superfluid or probably two layers, one being S symmetry, the other being P symmetry. The core of the star we honestly aren't sure about. It may not be the same for all pulsars. Some may be solid, some may be liquid. The Fermi energy is high enough to create bosons so Bose-Einstein condensates are possible. Technically, the Fermi energy is probably high enough to create strange quarks. In short, you have a star 20 km across, weighing the same as the Sun, with immense magnetic and electric fields (10^8 T and 10^9 Vcm^{-1} respectively) spinning on its axis up to several hundred times per second. This is extreme physics.

There is more. The first planets discovered beyond the solar system were orbiting a pulsar. Why there are planets round a pulsar is another question. The roundest known thing in the universe is the orbit of a pulsar round its companion star. It's round to 1 mm in the radius of the orbit. And if you drop anything on the surface of a neutron star, it hits the deck at half the speed of light. So, these are bizarre objects, hard to believe, but we are forced to believe in them.

Near misses

There have been one or two near misses in the past. In the late 50s or early 60s there was an open night at, I think, Flagstaff Observatory (Arizona). The person demonstrating the night sky had the telescope trained on the Crab Nebula (figure 4), and particularly on the Minkowski star, which we now know as the Crab Pulsar. A woman looked down the telescope and said "That star's flashing." The assistant explained to her about scintillation. "Yes," she said, "I'm an airplane pilot. I know the difference between random scintillation and flashing. That star is flashing." Nobody followed it up.

A few years before we discovered pulsars there was a 408 MHz survey of the sky. This survey required big radio telescopes and the observers got time where they could. In what they hoped was the last week of their survey, they were having problems with one of the chart recorders. One day in the early hours the recorder pen started sweeping regularly: bleep, bleep, bleep… The radio astronomer concerned said "Damn" and thumped the pen recorder: it stopped "misbehaving." Unfortunately he did not write anything in the logbook. If he had, they could have claimed a prior discovery for they were observing the pulsar PSR0328+54.

Lessons learned

What lessons have we learned? A lot that is politically incorrect in the current research climate! Having one's own equipment and knowing its foibles is very important. Common-user equipment gives us access to all sorts of things, but the observer doesn't know the equipment that well. Being a research student is important. I don't buy into the idea that our brains fade with age, but we do get other responsibilities, and we don't have the space and time that a research student does. As a student I was not goal-oriented and followed up on things that I could well have ignored – a mere quarter inch in 400 feet. We had moved into a new domain, a new area of phase space, with higher time resolution and more sensitivity. That was important.

Furthermore, we have neglected, incidentally, time-variability. The X-ray astronomers are alert to it, the radio-pulsar people are alert to it; gamma-ray astronomers are too, but only now are the optical astronomers starting to study "things that go bump in the night." It's a fascinating and under-researched topic. ❖

Portrait of a Decade *continued from page 1*

In 1999, Meg Urry repeated the survey and compared her results with those from 1992 (STATUS, June 2000; **http://www.aas.org/cswa/status/statusjun00.pdf**).

As the 10-year anniversary of the first Women in Astronomy meeting approached, the AAS Committee on the Status of Women in Astronomy (CSWA) decided to conduct the survey again, so that the results could be presented at the second Women in Astronomy conference at Caltech in July 2003. Meg Urry provided the original survey's data, questions, and list of institutions; Karen Kwitter contacted department chairs and other colleagues for help in gathering the data; and I compiled and analyzed the results and presented them at the WiA II meeting (**www.grammai.org/astrowomen/stats/poster.html**). Full data from all three surveys are now available online in HTML and Excel formats at **www.grammai.org/astrowomen/stats/**[1]. Each of the surveys had a near 100% response rate; together, the three comprise a uniform sample of the major astronomy programs in the U.S over the past decade.

With three comparable surveys spanning 11 years at our disposal, we have the opportunity to investigate whether and how quickly the representation of women in astronomy is changing. This article presents the results of that investigation. We first discuss the 2003 survey and other recent snapshots of women in astronomy. In section 2, we compare the 2003 CSWA survey results with those from the previous STScI surveys to assess changes over time. In section 3, we examine the past decade's results for individual institutions. Finally, in section 4, we address the limitations of these surveys and suggest strategies to guide future efforts in assessing the status of women in astronomy.

Jennifer Hoffman

Meg Urry

1. 2003 snapshot

To ensure that the 2003 data would be comparable with the earlier surveys, we used the same list of institutions and gathered the same information. Specifically, we asked each department chair to send us the numbers of men and women in his or her department at the following career ranks as of May 2003: graduate student, postdoc, assistant professor–faculty, assistant professor–research, associate professor–faculty, associate professor–research, full professor–faculty, and full professor–research. When addressing chairs of combined physics and astronomy departments, we asked for data representing astronomers only. Decisions regarding precisely whom to include and how to classify them were made by the individual chairs. We received responses from 35 of the 36 institutions in our sample (32 universities and 4 national research centers; see Table 1 for the full list), representing over 1600 Ph.D. astronomers and nearly 800 graduate students.

Universities
Boston University, Dept. of Astronomy
California Institute of Technology, Dept. of Astronomy
Case Western Reserve University, Dept. of Astronomy
Columbia University, Dept. of Astronomy
Cornell University, Dept. of Astronomy
Harvard University, Dept. of Astronomy
Indiana University, Dept. of Astronomy
Johns Hopkins University, Dept. of Physics and Astronomy
Louisiana State University, Dept. of Physics and Astronomy
Massachusetts Institute of Technology, Dept. of Physics
Northwestern University, Dept. of Physics and Astronomy
The Ohio State University, Dept. of Astronomy
The Pennsylvania State University, Dept. of Astronomy and Astrophysics
Princeton University, Dept. of Astrophysical Sciences
Purdue University, Dept. of Physics*
Rice University, Dept. of Physics and Astronomy
Stony Brook University, Dept. of Physics and Astronomy
University of Arizona, Dept. of Astronomy
University of California at Berkeley, Dept. of Astronomy
University of California at Los Angeles, Dept. of Physics and Astronomy
University of California at Santa Cruz, Dept. of Astronomy and Astrophysics
University of Chicago, Dept. of Astronomy and Astrophysics
University of Colorado, Dept. of Astrophysical and Planetary Sciences (no 1992 data)
University of Illinois at Urbana-Champaign, Dept. of Astronomy
The University of Iowa, Dept. of Physics and Astronomy
University of Maryland College Park, Dept. of Astronomy
University of Massachusetts, Dept. of Astronomy
University of Minnesota, Dept. of Astronomy
The University of New Mexico, Dept. of Physics and Astronomy (no 1999 data)
The University of Texas at Austin, Dept. of Astronomy
University of Virginia, Dept. of Astronomy
University of Washington, Dept. of Astronomy
University of Wisconsin-Madison, Dept. of Astronomy
Yale University (no 1992, 1999 data)*
National Research Centers
National Optical Astronomy Observatory
National Radio Astronomy Observatory
Smithsonian Astrophysical Observatory
Space Telescope Science Institute

* 2003 data from Purdue and Yale are included in the database but were not used in our statistical analysis: Yale was not one of the original 36 institutions, so no past data exist; 2003 Purdue data included physicists and were not comparable with past data.

Table 1: List of institutions included in the 2003 CSWA survey. All were also included in the 1992 and 1999 STScI surveys unless otherwise noted.

[1] Those already familiar with these web pages should note that they have recently moved along with me; I am no longer maintaining the old site at Rice University. Please update any links or bookmarks.

Jennifer Hoffman is an NSF Astronomy & Astrophysics Postdoctoral Fellow working with research groups at UC Berkeley and Lawrence Berkeley Laboratory on 3-D spectropolarimetric modeling of supernova ejecta. She also organizes local networking, outreach, and social activities aimed at developing a diverse support structure for women in physics and astronomy across educational and career levels. Meg Urry is Professor of Physics and Director of the Yale Center for Astronomy & Astrophysics. Her research is on active galaxies, notably blazars and obscured black holes. She was the organizer of both the 1992 and 2003 Women in Astronomy conferences.

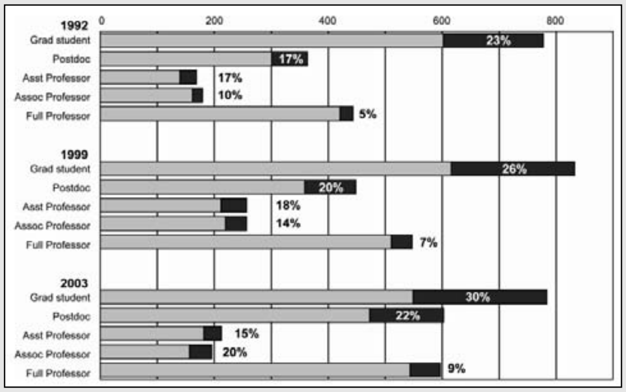


Figure 1: Number of male (gray) and female (black) U.S. astronomers in the 1992 and 1999 STScI surveys and the 2003 CSWA survey. Percentages represent the fraction of astronomers in each category who are women. Both tenure-track and research-track scientists are included. For source data, see **www.grammai.org/astrowomen/stats**.

Figure 1 shows our 2003 results along with the data from the 1992 and 1999 STScI surveys, which we discuss in section 2. "Research" and "faculty" tracks are combined in this figure. In Table 2, we compare our 2003 results for "faculty" only with the most recent survey data for astronomy from NSF, AIP, into and the Nelson Diversity Surveys conducted by Dr. Donna Nelson at the University of Oklahoma. (The NSF and AIP studies of bachelor's and Ph.D. students were comprehensive, covering several hundred degree-granting institutions each. The AIP study of astronomy faculty surveyed 38 stand-alone university astronomy departments. The Nelson Diversity Surveys considered the "top 50" astronomy institutions, drawn from NRC rankings and the 2003 AIP guide to graduate programs, including combined astronomy/physics departments but no national research centers.

Rank	NSF (1998-2002)	AIP (1999-2002)	NDS (2003)	CSWA (2003)
Bachelor's Recipient	35 %	37 %		
First-Year Grad Student		29 %		
Grad Student	29 %			30 %
Ph.D. Recipient	19 %	24 %		
Postdoc				22 %
Instructor/Adjunct		15 %		
Assistant Professor		23 %	22 %	20 %
Associate Professor		23 %	17 %	21 %
Full Professor		10 %	10 %	9 %

Table 2: Percentage of U.S. astronomers who are women, by rank. "Professor" ranks include tenure-track positions only. Data are the most recent available from each source. For more details and links to the source studies, see **www.grammai.org/astrowomen/allstats.html**.

Although differences in category definitions, years covered, and institutions included give rise to variations in results among the surveys, the overall picture is relatively coherent. Women currently earn over a third of the bachelor's degrees in astronomy awarded in the U.S., make up about 30% of the graduate population in astronomy, and receive one fourth to one fifth of the astronomy Ph.D.'s awarded. Fluctuating populations and differing categorization of postdocs and lower-rank faculty members make for larger uncertainties in these statistics, but women's representation at these levels appears to be comparable to that at the current Ph.D. recipient level. However, at the full professor rank, women make up at most one tenth of the population.

Figure 2 shows the distribution of male and female astronomers across ranks for the 1992, 1999, and 2003 surveys with tenure and research tracks combined. In 2003, nearly half the women in astronomy (48%) were graduate students, while a tenth (11%) were full professors or equivalent. Men in astronomy were evenly divided between graduate students and full professors (29% each). Postdocs, assistant professors, and associate professors made up roughly the same fractions of the male and female populations. We discuss changes in these distributions over time in section 2.

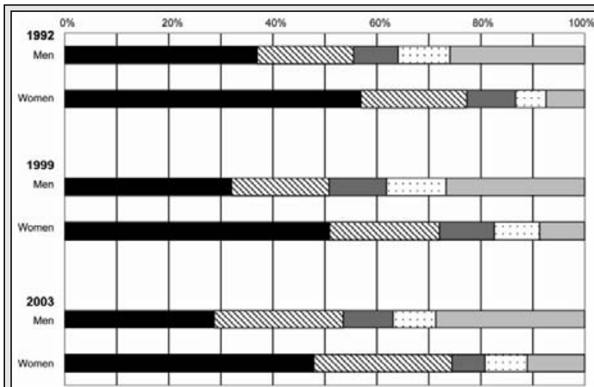


Figure 2: Distribution of U.S. astronomers among ranks in the 1992 and 1999 STScI surveys and the 2003 CSWA survey. From left, the bars represent graduate students, postdocs, assistant professors, associate professors, and full professors both tenure-track and research-track scientists are included. For source data, see **www.grammai.org/astrowomen/stats/**.

Rank	"Faculty"	"Research"	Combined
Assistant Professor	(20 ± 5) %	(11 ± 3) %	(15 ± 3) %
Associate Professor	(21 ± 5) %	(19 ± 5) %	(20 ± 3) %
Full Professor	(9 ± 2) %	(9 ± 2) %	(9 ± 1) %

Table 3: Percentage of U.S. astronomy professors in the 2003 CSWA survey who are women, by rank and track. For source data, see **www.grammai.org/astrowomen/stats/**.

Table 3 shows the 2003 CSWA survey results for astronomy faculty members divided between "research" and "faculty" tracks. We see a difference between the two only at the assistant professor level, where women appear to be better represented among tenure-track professors. Although the definitions of these two categories may vary from place to place, especially between universities and national research centers (the distinction in each case was made by the departmental representative), we cautiously interpret these data to suggest that women are not currently more likely than men to hold soft-money positions—in fact, the reverse may be true at the assistant professor level.

2. Changes over time

How has the situation evolved since 1992? Figure 1 shows the numbers and percentages of women and men at each rank in the three years of the survey. The percentage of women has been steadily, if slowly, increasing with time at nearly all ranks. The only exception in our surveys is at the assistant professor rank, where the inclusion of research-track astronomers results in an overall decrease between 1999 and 2003; see below for further discussion. The number of female graduate

Continued on page 10

Portrait of a Decade *continued from page 9*

students increased from 1999 to 2003, even as the total graduate population decreased to near 1992 levels. Since 1992, then, the increase in graduate women has nearly exactly compensated for the decrease in graduate men, indicating a true change in the composition of the field (as opposed to a change in the number of students overall). The total number of astronomy postdocs increased sharply from 1999 to 2003, with similar growth rates for men and women. At the same time, the number of assistant and associate professor positions both declined, perhaps suggesting a tightening job market.

We can use these three datasets to assess whether there have been discrepancies in the past 11 years between the rates at which men and women advance through the academic career ranks. If it takes roughly 6 years to advance from graduate student to postdoc and from postdoc to assistant professor, we can assume that in the years between the 1992 and 1999 STScI surveys, the majority of both the "grad student" and the "postdoc" cohorts who remain in the field had the opportunity to advance to the next career stage. If the factors governing this advancement affected men and women equally, the percentage of women should have remained constant across this transition. That is, we should find that women made up the same proportion of postdocs in 1999 as grad students in 1992 and the same proportion of assistant professors in 1999 as postdocs in 1992. (Beyond the assistant professor level, the progression takes varying amounts of time and is no longer as predictable.) Table 4 shows that this is approximately the case. Dividing the number of 1999 postdocs by 1992 grad students, we find that 60% of the men advanced to the postdoc level while roughly half the women did; the error bars are large enough that the difference is not significant (note that these figures have been corrected from the report by Urry in STATUS, June 2000). We also see no significant difference in the fraction of men and women (~70% in each case) who advanced from the postdoc to the assistant professor level between 1992 and 1999. These data indicate that the women in this sample neither experienced widespread discrimination nor received preferential treatment as a result of affirmative action policies; instead, they obtained postdoc and assistant professor positions at a rate proportionate to their presence in the candidate pool.

Since only four years elapsed between the 1999 and 2003 surveys, the situation is not as clear-cut—that is, the time interval is too short for all members of the 1999 grad student cohort to have moved on. To perform the same analysis using the 2003 data, therefore, we estimated the numbers of grad students and postdocs in 1996 by linearly interpolating between the 1992 and 1999 values. Table 5 shows the results, which suggest that the situation may have worsened for women in recent years. While a larger fraction of women (65%) advanced from the grad school to the postdoc level between 1996 and 2003 than between 1992 and 1999, the fraction of men who advanced was even higher (78%). At the transition to assistant professor, both men and women in our survey saw their chances dwindle: between 1996 and 2003, only 55% of men advanced from postdoc positions, while the fraction of women was even lower at 40%. We stress that while the 1996 figures are reasonable estimates based on the 1992 and 1999 data, they do not reflect actual measurements. Nevertheless, these results are troubling; they suggest that even after approximate gender equity is attained (as seems to have been the case between 1992 and 1999), it does not automatically persist.

	1992 Grad Students	1999 Postdocs	% Advancement
# Men	602	359	(60 ± 4) %
# Women	176	90	(51 ± 7) %
% Women	(23 ± 2) %	(20 ± 2) %	
	1992 Postdocs	**1999 Asst. Profs**	**% Advancement**
# Men	301	212	(70 ± 6) %
# Women	63	45	(71 ± 14) %
% Women	(17 ± 2) %	(18 ± 3) %	

Table 4: Comparison between adjacent ranks in 1992 and 1999.

Assuming the percentage of women did in fact decline in both these cases as the 1996 grad student and postdoc cohorts moved upward, it is logical to ask at what stage(s) the decline occurred. We estimated from the STScI surveys that 25% of the astronomy graduate students in 1996 were women; the NSF reported this figure to be 26% (NSF, *Graduate Students and Postdoctorates in Science and Engineering: Fall 2001*). The NSF further reported that 19–22% of the 2002 doctoral degrees in astronomy went to women between 1997 and 2002 (NSF, *Science and Engineering Doctorate Awards: 2002*), suggesting that these female students may have experienced greater attrition rates during graduate school than their male classmates. Another possible explanation for the decline we observed is that the women of the 1996 cohorts remained disproportionately long at the graduate and postdoctoral levels. The increase in the postdoc population from 1999 to 2003, combined with the decrease in the assistant and associate professor populations, suggests that a less favorable job market may also have contributed to the loss of women from the field during this period.

Our data suggest yet another contributing factor. We see from Table 3 that in 2003 there were proportionately fewer women in assistant research professor positions than in assistant tenure-track professor positions; using these disaggregated data, we find that 111, or 33% (± 4%), of the estimated 1996 male postdocs became assistant research professors, while only 13, or 17% (± 5%), of the female postdocs did. By contrast, approximately equal percentages of men and women (71 men, 21% ± 3%; 18 women, 23% ± 6%) became assistant tenure-track professors. These results suggest that while tenure-track hiring still occurs at equal rates for men and women, either there exists a bias in hiring for research-track positions or women now have a lower tolerance than men for these positions. Perhaps the women who would otherwise round out these proportions are deciding to leave the field rather than take soft-money jobs. However, because we have no information regarding the gender makeup of either the faculty applicant pool or the group of people who leave the field each year, we cannot assess the relative roles of these effects in shaping the percentages presented here. In section 4, we discuss what additional information would allow us to refine our analysis of the academic pipeline in future surveys.

	1996 Grad Students (est.)	2003 Postdocs	% Advancement
# Men	610	473	(78 ± 5) %
# Women	199	130	(65 ± 7) %
% Women	(25 ± 2) %	(22 ± 2) %	

	1996 Postdocs (est.)	2003 Asst. Profs	% Advancement
# Men	334	182	(55 ± 5) %
# Women	78	31	(40 ± 8) %
% Women	(19 ± 2) %	(15 ± 3) %	

Table 5: Comparison between adjacent ranks in 1996 and 2003. 1996 figures were estimated by linear interpolation between 1992 and 1999 values.

The distribution of male and female astronomers across ranks has changed steadily since 1992 (Figure 2). Among both groups, the percentage of full professors has increased, while the percentage of grad students has decreased. Interestingly, the rates of change in both groups are very similar, so that the population of women in astronomy is still more heavily weighted toward the young end of the spectrum than is the population of men.

Our survey results indicate that the situation for women in astronomy has improved in many ways over the past decade. Women's representation continues to increase at all levels, and the pipeline appears to have treated women and men equally at least part of the time. This is good news to those concerned about the status of women in the field. However, we found troubling indications that women and men do not always progress through the career ranks in proportion to their representation at lower levels. There are many possible reasons for these differences, which we can only begin to analyze; our data suggest that one factor may be underrepresentation of women on the research track. We feel these results should serve as a warning that despite welcome gains in many arenas, the work of building an equitable environment for women in astronomy is not yet done; hard-won improvements in the status of women in astronomy require continual maintenance.

3. Individual institutions

We can also use the STScI and CSWA surveys to track the representation of women over time at particular institutions. Our compilation of 1992, 1999, and 2003 survey data sorted by institution is available online in HTML and PDF format at **www.grammai.org/astrowomen/stats/**. For simplicity of presentation, we combined the research and faculty tracks in creating the compilation table; disaggregated data for each institution may be found in the 2003 database on the same page. We stress again that all decisions about classification was done by the departmental representatives. We also note that although this table includes percentages, these are not useful indicators in many cases where the sample size is small. We urge caution and common sense in evaluating these numbers.

We invite all interested parties to read the compilation table carefully and discuss their institution's results with their colleagues. In the discussion that follows, we will not name particular institutions, but we hope that the public availability of these data will encourage widespread dialogue about the environment for women, both negative and positive, at institutions across the country. We hope students and job seekers will use these results to inform their decisions, and we hope those who believe their institutions' records need improvement will look for ways they can help effect that change.

Here are some interesting results from this dataset:

- Of the 36 institutions surveyed, there are now (as of 2003) six without a woman at a full professor rank. Of these six, two have fewer than three full professors; the others have 4, 6, 7, and 12). Four of the six are combined physics/astronomy departments.
- As of 2003, the largest number of female full professors at any institution is 3; the largest number of male full professors at any institution is 42.
- Some institutions have dramatically improved the number of women among their professorial ranks since 1992, while others have not. Table 6 shows two extreme examples. Institution A had no female professors in 1992. It

	1992		1999		2003	
Institution A	Men	Women	Men	Women	Men	Women
Asst Professors	3	0	4	4	3	2
Assoc Professors	2	0	4	0	1	1
Full Professors	7	0	10	1	15	2
Institution B						
Asst Professors	0	0	1	0	4	0
Assoc Professors	2	0	1	0	2	0
Full Professors	7	2	11	2	12	2

Table 6: Numbers of male and female professors from two institutions in the STScI and CSWA surveys.

Continued on page 12

Portrait of a Decade *continued from page 11*

has since promoted two women and eight men to full professor rank, and currently has three more women and four more men at lower ranks. Institution B has had two female full professors since 1992, which is unusual and admirable. However, since then it has hired nine men and promoted five men to the full professor level. No women have apparently been hired during this time.

• Table 7 illustrates two other interesting situations. At some institutions, the overall percentage of women has increased, but the long-term situation has not improved; at Institution C, the number of female faculty members remains nearly unchanged since 1992, while more postdocs of both genders have been hired and male full professors have left or retired. At others, women move up the professorial ranks, but then apparently leave; Institution D is an example.

	1992		1999		2003	
Institution C	Men	Women	Men	Women	Men	Women
Postdocs	0	0	10	1	14	3
Asst Professors	1	1	1	0	2	0
Assoc Professors	1	0	1	1	2	0
Full Professors	16	1	16	1	12	1
Institution D						
Asst Professors	0	1	2	0	2	0
Assoc Professors	0	0	2	0	1	0
Full Professors	7	0	4	1	6	0

Table 7: Numbers of male and female scientists for two more institutions in the STScI and CSWA surveys.

• There seems to be no relation between the prestige of an institution and the representation of women among its ranks. Neither the 2003 percentage of women among faculty members nor the 2003 percentage of women among all Ph.D.s in the university departments we surveyed correlates with NRC ranking (NRC, *Research-Doctorate Programs in the United States: Continuity and Change,* 1995). All examples listed here refer to top-30 institutions as ranked by the NRC, and the most extreme positive and negative examples given by Fran Bagenal in this issue both come from Ivy League schools. We also find no clear-cut trends with institution size.

• Women tend to be slightly better represented at public universities and in standalone astronomy departments than at private schools and in combined physics/astronomy departments. The differences are not large, but they persist over the three surveys.

4. Comments and recommendations

The 2003 CSWA survey had several limitations. We encountered difficulties in standardizing the professorial ranks and faculty/research distinction from institution to institution. Though we attempted to keep the sample as similar as possible to the 1992 and 1999 samples, this occasionally proved difficult as well; it was not always clear which criteria had been applied in the past, or even which scientists at a given institution should be considered astronomers! Statistical complications included small numbers and the possibility of counting people with multiple affiliations more than once.

However, we feel this survey, especially in combination with the previous two, provides a robust view of the overall progression of women and men into our profession. We urge the CSWA to continue conducting this survey with the same sample on a regular basis. Ideally, the next survey should occur in 2005-2006, at which time the 1999 grad student and postdoc cohorts should have moved up to the next career rank. We entertain fantasies of a world in which each astronomical institution submits yearly reports to the AAS containing the modest amount of information we collected for this survey; until this ideal comes to pass, however, one repetition of the survey every 6 years would still provide a valuable long-term record of the gender makeup of the field. We consider it important to continue gathering information on research or soft-money astronomers, and urge the CSWA as well as other organizations to include them in future surveys. As we have seen, variations in the characteristics of these groups can have significant effects on the overall composition of the field. We also recommend collecting data on yearly Ph.D. production at surveyed institutions; this would not only allow better analysis of institutional hiring practices, but also inform the decisions of prospective graduate students.

Like any good scientific study, this survey raised many new questions that were beyond its scope. Future studies can complement this one by focusing on more narrowly-defined groups and seeking more detailed information. We add ours to the many voices raised at the Women in Astronomy II conference in support of a long-term longitudinal study sponsored by the AAS. Only by tracking the specific career paths of well-defined cohorts of subjects can we address such issues as the possible differential attrition of women in graduate school or the gender makeup of faculty applicant pools in a given year. We also point out the importance of soliciting information from people, especially women, who leave the field; if we simply assume that only the “best” people remain, we blind ourselves to the potential discovery of forces detrimental to the community as a whole. Finally, we reiterate our main finding, which agrees with that of Bagenal in this issue: despite many improvements, men and women in astronomy still experience differential attrition as they advance in their careers. Simply monitoring the situation with surveys and demographic analysis will not solve the problem; we urge astronomical organizations and individual members of the community to continue their efforts to encourage and retain women in the profession, and to use the information in these surveys as a guide to assessing the environment for women within the ranks of individual institutions. ❖

Fran Bagenal is Professor of Astrophysical and Planetary Sciences at the University of Colorado. She studies magnetic fields and plasmas surrounding planets. While she encourages women scientists to learn to say "no" to more tasks, she admits she was co-opted by Meg Urry to be program chair of Women In Astronomy II and to edit STATUS.

The Leaky Pipeline for Women in Physics and Astronomy

by Fran Bagenal

The science career pipeline is being hotly debated. Is it preferentially leaky for women? Is it an outdated metaphor for a complicated issue? At the Women In Astronomy II (WIA II) conference held at Caltech in June 2003, recent data on faculty numbers in physics and astronomy indicated the leaky pipeline to be fixed. I was prompted to roll up my sleeves and dig down into the data. I found there is indeed encouraging news for some women at the faculty section of the pipeline. But locally there remain enormous variations among institutions and overall very serious differential leaks persist for women at college levels. Moreover, the overall input to the pipeline, the total numbers of undergraduate degrees in physics, is limiting growth of the field. The latest AAS membership data reveals a cohort of young astronomers comprising a startling high 60% of women, providing an opportunity to study a group as they move through the pipeline and ask these women what factors shape their career paths.

The Numbers: Pipelines and Scissors

The first time I recall seeing "the pipeline" used to refer to the flow of people along careers in science was in Sheila Widnall's AAAS presidential address "*Voices from the Pipeline*" (Widnall 1988, see excerpt in this issue). Her address began with the frequently-repeated policy refrain that the nation is in dire straits and that we need to train more people in science and engineering:

"Demographic trends predict a future significant drop in the numbers of white males of college age, who have been the dominant participants in science and engineering. The likely effects of these trends on scientific and engineering personnel have been documented by the NSF and OTA of the US Congress. If current participation rates continue, the future pool of science and engineering baccalaureates is projected to show a significant drop. We have now passed the peak of US graduate students available from traditional pools and are headed down the slope to a 26% decrease in the pool by the late 1990s."

Fran Bagenal

In reality, the number of degrees in science and engineering, did not drop precipitously (they increased through the 80s and 90s, partly due to an increasing participation of foreign students), but a recent National Science Board report on the science and engineering workforce repeats the refrain (NSB 2003). As I shall discuss below, the numbers for the physics profession remain worrisome.

For Widnall the demographic trends were the entree for a discussion of women in science. Based on a 1985 OTA report she presented a grim picture:

"Of an initial cohort of 2000 male and 2000 female students at the ninth grade level only 1000 of each group will have sufficient mathematics capabilities to remain in the science pipeline. When the two groups are followed to the end of high school, 280 men and 220 women will have completed sufficient mathematics to pursue a technical career. A major drop in women students occurs with career choice upon entering college, with 140 men and 44 women choosing scientific careers."

She presented a dramatic diagram (Figure 1a) that shows this continued steep decline in numbers through graduate school. "Of the original 2000 students in each group, five men and one woman will receive the PhD degree in some field of natural science or engineering." I show another version of this leaky pipeline diagram in Figure 1b.

In her paper Widnall concluded from the steeper slopes in Figure 1a that the most fruitful areas to concentrate on would be the initial career choice (entering college) and graduate school years. The remainder of her presidential address is a very interesting summary of surveys of graduate students at Stanford and MIT. Her findings are not likely to surprise a reader of STATUS (issues of self-esteem, aggressive styles of communication and occasional egregiously bad behavior) and it is impressive that she used her presidential address to highlight the issues.

Moving forward 15 years to 2003, how has the leaky pipeline changed? From here onwards I shall limit my discussion to physics and astronomy

Continued on page 14

Leaky Pipeline *continued from page 13*

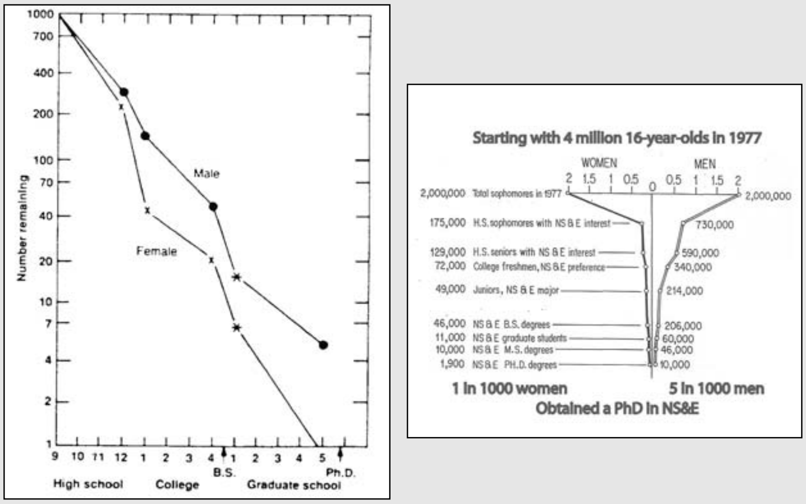


Figure 1a and b: (a) For every 4000 high school students, 2000 have enough math background to study science, with equal numbers of men and women. Starting with 1000 each of men and women, only a fraction remain in the science and engineering pipeline though college and grad school, resulting in five men and only one woman with PhDs. From Widnall (1988). (b) The leaky pipeline of natural science and engineering (based on NSF data).

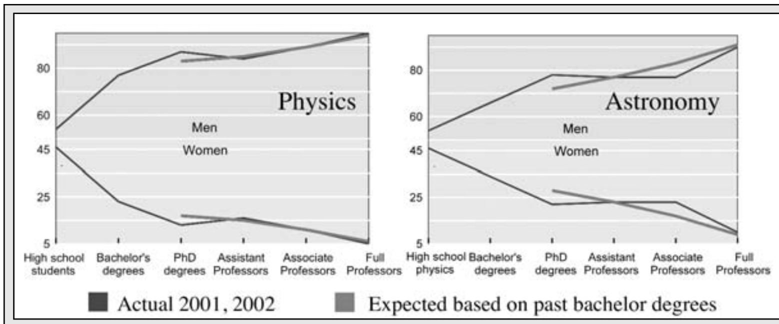


Figure 2: The "scissors diagram" showing the actual and expected percentage of women and men in physics and astronomy in the US. From Ivie (2003).

rather than address the whole of science and engineering (for which the National Science Board has a 2003 workforce report, NSB 2003). The statistics division of the American Institute of Physics has been gathering data for many years for the physical science profession. At WIA II Rachel Ivie presented recent AIP studies of women in physics and in astronomy (Ivie and Nies 2003). Their version of the pipeline issue is presented as the "scissors diagram" in Figure 2. Rather then show absolute numbers (as in Figure 1), these scissors plots show the percentage of women at each stage. Thus scissors plots show the *differential leak* of women along the pipeline.

Figure 2 shows a huge leak between high school and PhD. The net drop from high school to college is a little less steep for astronomy, a little worse for physics than that shown for all of science and engineering in Figure 1. The post-PhD story for physics and for astronomy is more encouraging, the actual percentage follows that predicted from earlier production of bachelor degrees, and slightly better in the case of astronomy. This suggests that all we need to do is wait for the increasing supply of women to come through the pipeline and the scissors will slowly close up. Now the word is spreading that the leaks in the pipeline are all fixed.

This inference that everything is hunky-dory did not sit well with many of us women astronomers who are actually (swimming?) in the flow. It just does not to reflect our own experiences. To further examine the issue, I took Rachel Ivie's data and the 2003 astronomy data compiled by the CSWA (Hoffman and Kwitter 2003) to produce Figure 3.

Graduate School Leaks

In her WIA II presentation Ivie showed the percentage of degrees in physics and in astronomy awarded to women from 1966 to 2001 for bachelor and PhD degrees (top panel of Figure 3, based on Ivie and Nies 2003). Each profile shows a roughly factor of four increase in the percentage of women getting degrees over the past 30 years. The percentages are nearly a factor of two higher for astronomy than physics, but also more erratic due to much smaller (factor of 10-20) absolute numbers. Estimating that the average time between degrees to be six years, I then translated the bachelor profiles to the right by six years. Sure, only a fraction of those getting bachelors degrees go on to complete a PhD, but if the pipeline were not differentially leaky for women, the translated curves should line up with the PhD curves. For physics there is clearly a substantial difference between the current actual percentage of ~13% and the expected value of 17-18%. For astronomy the erratic nature of the curves muddies the story, but for the past 7 years the award of PhDs to women has been persistently below expectations based on the percentages of women with bachelor's degrees (e.g., in 2001 the expectations based on bachelor's degree production 6 years earlier would be that 30% of PhDs would go to women when the actual numbers are only 3/4 of these expectations with 22% of PhDs going to women). One might imagine that women who have children during graduate school might take a little longer to get a PhD but the average time to PhD would have to be many additional years to make the curves overlap. Thus, the differential leak in the graduate school section of the pipeline remains substantial, the underlying causes of which our profession should investigate. Discussions at WIA II confirm that the poor work environment reported by Widnall (1988) still apply to physics and astronomy programs across the nation.

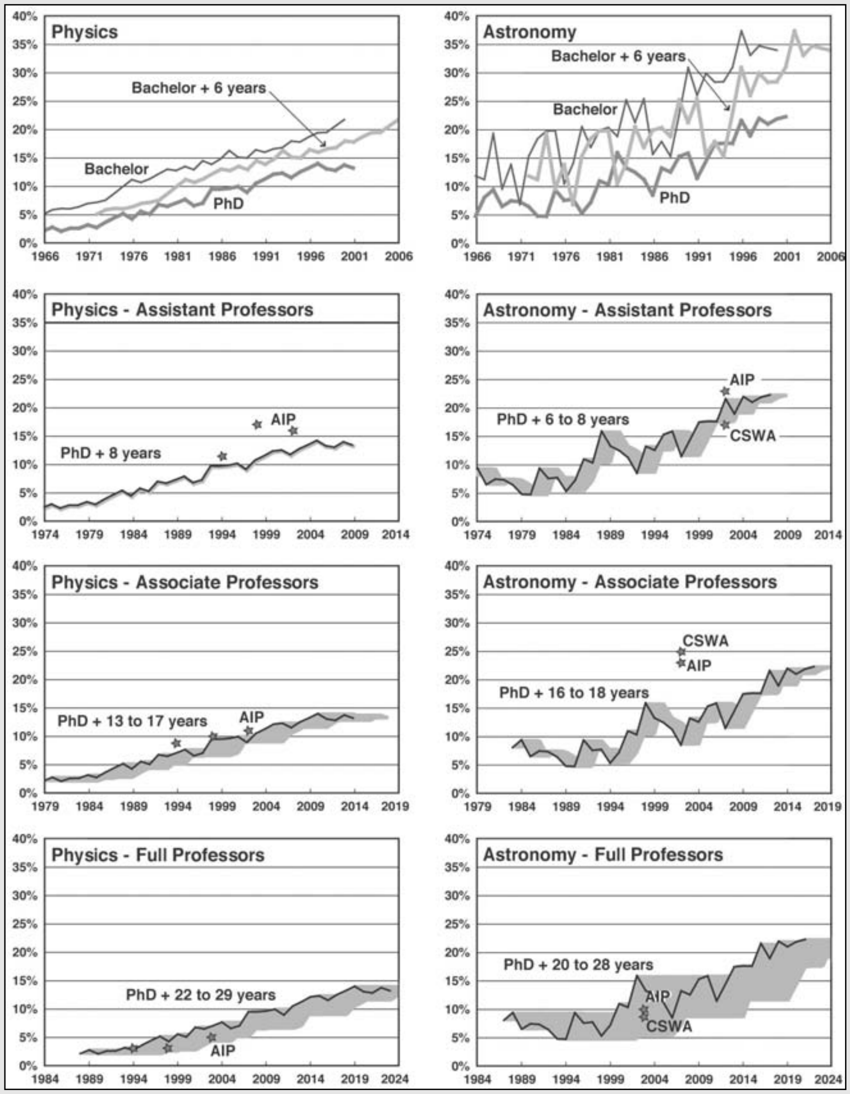


Figure 3: Actual and expected percentages of women with degrees (top) and in faculty ranks (lower three pairs of panels) for physics (left) and astronomy (right). The expected percentages of women in the faculty ranks are based on translating the PhD curves in the top pair of panels by the range of mean number of years since PhD at each rank shown in Table 1. The curves are based on Ivie and Nies (2003). The actual faculty numbers are based on AIP statistics (Ivie and Stowe 1998, Ivie and Nies 2003) and on the CSWA 2003 survey (Hoffman and Kwitter 2003).

Faculty Leak Stemmed?

To investigate leaks further along the pipeline I took the PhD time curves and translated them according to the average number of years since PhD for the three main faculty ranks (shown in Table 1). The increase in hiring of women is reflected in the smaller mean number of years since PhD for all ranks. To calculate the expected percentages of women in these three ranks for physics and for astronomy I translated the PhD curves by the full range (mean for women to mean for men), shown by the broad, paler curves in Figure 3. The black curves are the expectations based on the mean years for women. For comparison, the actual percentages of women in these ranks are shown by stars, based on data from AIP and from the 2003 CSWP survey of astronomy.

Figure 3 shows that for assistant professors in physics over the past decade the percentage of women has been above expectations. In astronomy the percentages of women assistant professors quoted by the AIP and CSWA straddle the curve. For associate professors the physics record remains just above expectations while for astronomy the percentage of associate professors (23-25%) seems to soar above the "pipeline values" of 10-15%. Extrapolations over the 20-30 years between PhD and full professor are somewhat risky but the actual values for the full professors

Continued on page 16

Leaky Pipeline *continued from page 15*

fall below but comparable to expectations. Thus, indeed, when one looks at national statistics the faculty section of the pipeline does not seem to be differentially leaky for women. We eagerly await the impact over the next decade of the high fractions of women at assistant and associate levels for physics and astronomy on both the statistics for full professors and on numbers of women students.

No Time for Complacency

While the percentages of women in faculty positions are indeed quite encouraging, there are several reasons to remain cautious before the community pats itself on the back and dismisses the leaky pipeline as history. For example, when one looks at the results of the 2003 CSWA survey of astronomy faculty one finds huge variations among institutions. Several astronomy departments have extremely few or no women faculty at all. Table 2 compares two universities with large, strong astronomy departments – Columbia and Cornell – that illustrate this wide range in representation of women. Departments such as Boston University where the number of women faculty increased from zero in 1992 to 5 out of 24 in 2003 show that change is possible. Millie Dresselhaus (AAAS president who reviewed of the status of women at many physics departments) noted that sometimes it only takes one faculty member - male or female – making an effort to affect substantial change. Yet, even when someone on a search committee makes an effort to consider women candidates they are faced with tendencies for lower application rates among women and higher probability of a "2-body problem" (Figure 4). Nevertheless, the CSWA survey demonstrates that many departments have surmounted these obstacles. Denice Denton, Dean of Engineering at University of Washington, presented at WIA II a host of ways to increase the hiring of women (Denton 2003). A useful vehicle for change can be an external review by a group such as the APS Committee on the Status of Women in Physics which offers to visit a department and provide advice.

Mean Years Since PhD		Physics	Astronomy
Full Professor	Male	29	28
Full Professor	Female	22	20
Associate Professor	Male	17	18
Associate Professor	Female	13	16
Assistant Professor	Male	8	7
Assistant Professor	Female	8	6

Table 1: Mean years since PhD for three main faculty ranks in 2002 (Ivie and Nies 2003).

		1992			**1999**			**2003**		
		Men	Women	%	Men	Women	%	Men	Women	%
Cornell	Asst Profs	2	0	0.0	4	0	0.0	1	0	0.0
	Assoc Profs	4	0	0.0	2	0	0.0	2	0	0.0
	Full Profs	13	1	7.1	16	1	5.9	19	1	5.0
Columbia	Asst Profs	4	2	33.3	5	3	37.5	4	3	42.9
	Assoc Profs	2	1	33.3	5	1	16.7	6	1	14.3
	Full Profs	7	0	0.0	9	1	10.0	11	3	21.4

Table 2: Data from the CSWA 2003 survey of faculty in astronomy (Hoffman and Kwitter 2003).

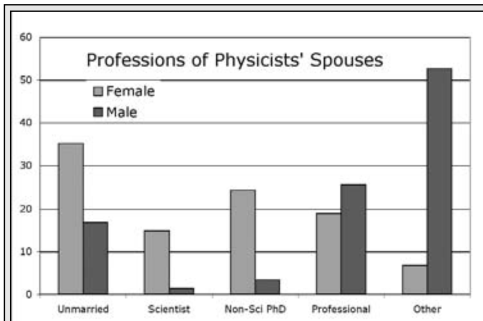


Figure 4: Survey of the profession of physicists' spouses shows that a large fraction of women physicists tend to be married to other scientists. As a result, women physicists in search of a job are more likely than men to be constrained by the availability of a position for a scientist spouse. Anecdotal evidence suggests this tendency is even stronger for astronomers. (Data from 1990 U.S. Census published in Xie and Shauman 2003).

Finally, in her presentation at WIA II Margaret Kivelson (UCLA) cautions that in her experience of academia since the 60s there can be regressions. Pointing out that after a steady rise in the 70s and 80s, the current (total) faculty hires at UCLA show a sharp decreasing trend in the percentage of women, she warns, "It takes effort even to keep from losing ground."

Broken Metaphor?

The faculty path is only one branch of the pipeline after PhD. The are many other career paths of successful, productive physicists and astronomers at research labs, in industry, as journalists, etc. While it is important that those institutions who train future generations of scientists include a substantial fraction of women, it is just as important that we do not lose valuable assets, often trained at significant expense, through leaks in the pipeline elsewhere in the system. In fact, it may just be that the fraction of women is much higher in these "alternative" career paths. Sadly, it seems that attention is paid almost exclusively to statistics of the academic track. We urgently need similar studies of demographics of all post-PhD branches of the pipeline.

Some people argue that the whole concept of a pipeline is inappropriate. It implies scientists are passive particles carried along by a flow over which they have no control. In a recent book Women in Science: Career Processes and Outcomes (reviewed by Rosser 2003), sociologists Yu Xie and Kimberlee Shauman argue that the pipeline metaphor is not appropriate because no simple theory explains the dearth of women in science and no one policy will provide a simple solution. Furthermore, they claim that the pipeline metaphor implies a single means of entry and does not allow for women entering science and engineering at different stages. In a similar vein, the common tendency for discussions to revolve around "the perfect trajectory" from school through college to a faculty position was strongly criticized at WIA II.

Personally, I do not believe women scientists think of themselves as passive particles and, naturally, we should encourage women to take active control of their destiny. While I accept that we need to examine – and celebrate - the multiple professional branches of our field, I argue that the pipeline metaphor remains a very valuable one. It is naïve to believe that one can enter a career in physics or astronomy except via a substantial number of years along what is undeniably a fairly uniform, standard pathway of college education in math and physics. This is a reality of a rigorous scientific profession and cannot be changed because sociologists believe people should be entitled to pick and chose a random path through life. The fact that many, many women have found satisfying careers in science does not mean, however, that the pipeline couldn't do with some improvements (e.g. with a healthier work environment, ways to handle 2-body problems, accommodation for families, etc). It has been obvious all along that there is no single "silver plug" that will stem the leak of women from scientific professions. Yet, the metaphor has been useful for drawing attention to the problem (and proposing solutions) with our colleagues, with administrators and with funding agencies. The pipeline has branches, is leaky in places and we need to find better ways to accommodate having a family along the way - but it isn't broken!

Watch the Inflow

While the pipeline branches after the PhD, the input to the conduit is largely restricted to those with undergraduate degrees in physics or astronomy (plus a few from mathematics). To a large extent, therefore, the input to the pipeline is critically dependent on the numbers of physics and astronomy degrees.

Figure 5 shows that the total numbers of degrees (both bachelor and PhD) for physics is static (one might even say oscillatory with a 20-year period). There is a glimmer of hope that the number of physics bachelor's is at last swinging upward, helped by the slow increase in women attaining physics degrees. For astronomy the trends are more positive but the numbers are much smaller.

Over the past few years there have been several investigations of causes of the low graduation rates in the sciences and physics in particular (e.g., Tobias 1994, Seymour and Hewitt 1997). They conclude that many of the aspects of physics undergraduate education that lead to students

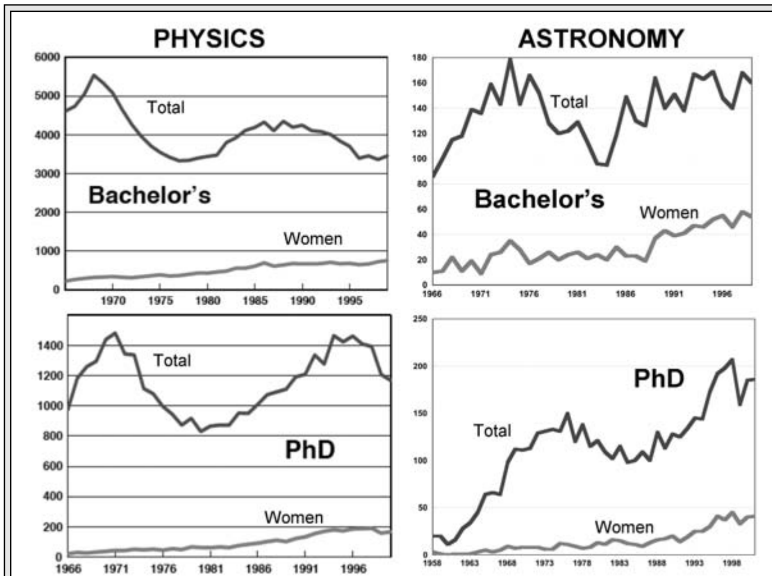


Figure 5: Numbers of bachelor's and PhD degrees awarded for physics (left) and astronomy (right). From Ivie and Nies (2003).

dropping physics are opinions generally shared by those who persist – the "stickers." The stickers just put up with what is all too often poor instruction and less than welcoming attitudes. The attitude of many physics faculty and TAs, that only the very brightest, toughest, nerdliest can stay the course, is stifling the field. At the same time, there are some shining examples of faculty and departments where the physics teaching is improving by leaps and bounds (e.g., see Tobias 1992, NRC 1999, McCray et al. 2003). Recent issues of *Physics Teacher or the American Journal of Physics show* examples. The AAPT has week-long conferences and AAS meetings have sessions on education. Yet, there are still departments, many at the better universities, where the teaching methods have barely changed since the turn of the century – the 19th century. *The one factor that could most radically improve the pipeline – in terms of both absolute numbers and to fix the differential leak of women – is to improve the quality of experience for undergraduate students taking physics courses.* This is something over which those of us who are faculty in physics and astronomy have some control and we need to act.

At the same time, improving the undergraduate experience is not just for faculty. There are several things that those earlier in the pipeline can do to help those following behind them. One issue that concerned me when I was on the graduate admissions

Continued on page 18

Leaky Pipeline *continued from page 17*

committee in my department was that many of the applicants had little idea about applying to graduate school. The GRE scores in physics were highly erratic and poorly correlated with GPA in physics courses. Few letters from the students conveyed the information we were looking for and many students picked faculty who barely knew them (or had no idea what to say) to write references. This is not necessarily the student's fault. How is a brilliant student at Podunk College supposed to know these things? Or, for that matter, how are students at Stanford and MIT supposed to learn that the name on their undergraduate degree means diddly-squat when they have Cs in physics or their physics GRE score is in the 4th percentile? These are things best learned from graduate students and post-docs who make the effort to mentor their local undergraduates or the laboratory researcher who talks to the summer interns about their careers. For that matter, think of the potential impact of each undergraduate who gets fired up by a research project visiting a couple of local high school physics classes.

Improving the undergraduate experience is key to the livelihood of our profession. But it takes more than a change in administrative policy to improve the quality of the work environment. Indeed, to quote Meg Urry's report on WIA II in the AAS newsletter "some undergraduate women report troubling, hostile environments, at the hands of their young male colleagues - notably, it isn't a story of older, traditional astronomers who just can't change, it's a new generation of arrogant and overly-entitled young men who apparently can't credit young women with intelligence, dedication, or a future in astronomy." None of us can afford to condone such behavior. Whether as a director of a lab or as "just another particle in the flow" we all need to speak out.

One of the most inspiring moments of the WIA II conference was the applause for the 2003 AAS statistics. Kevin Marvel, Deputy Executive Officer of the AAS, presented the membership statistics showing women now comprise 60% of the 18- to 24-year-old membership (Figure 6). Credit is suspected to be partly due to the enhanced support at NSF for the REU program which supported research projects for undergraduates, many of which have been presented at recent AAS meetings. This large group (75 under 23, 530 under 28) provides a great opportunity to follow a cohort, including substantial number of young women, along the pipeline and to study what factors influence their career choices.

Conclusions

1. There remains a significant differential leak of women in graduate school along the academic pipelines for both physics and astronomy. The percentages of PhDs awarded to women in 2001 are 13% and 22% for physics and astronomy respectively while the expectations based on the percentages of women obtaining bachelor degrees in these two fields are 18% and 30% respectively. *Until these leaks are stemmed, the flow of women into higher positions will be limited.*

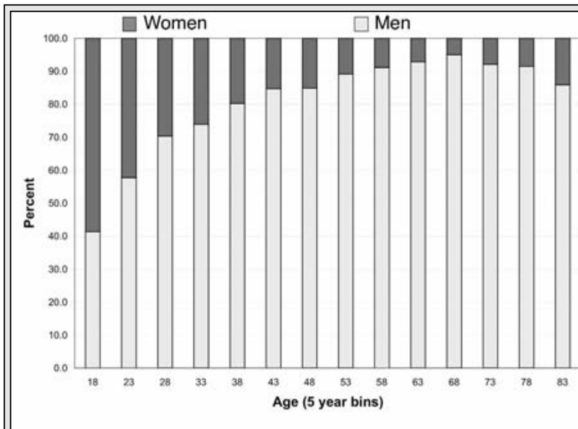


Figure 6: The membership of the AAS shows that in 2003 the fraction of women in the 18 to 23 age range has increased to nearly 60%. From Marvel (2003).

2. The statistics for faculty in physics and astronomy show that the percentages of women in the three main professorial ranks approximately match expectations based on past PhD percentages. There is encouragement in these national statistics where the actual percentage of women physics assistant professors is higher than expectations and the percentage of women astronomy associate professors is substantially higher. Past experience warns against complacency in the face of good news, however, to avoid regression to a less favorable state. *While the national news is encouraging, the local statistics (as demonstrated by the CSWA survey of women faculty in astronomy) show enormous variations across the country where several of the top university departments still have very low percentages of women faculty.*

3. We cannot expect a large increase in the flow into the pipeline in the near future. The trend in the absolute number of graduates with bachelor's degrees in physics is just starting to increase after a decade of decline from 4300 (in 1986) to 3300 (in 1996). The small number of astronomy degrees (~150 per year) has been slowly rising, mainly due to increasing numbers

of women. These slow-growth trends are disturbing. Who will be the future astronomers to analyze data from the new telescopes and missions planned for the next decade? Who will replace the faculty retiring from the 60s hiring bulge? Improving high school and college physics education remains a national imperative.

4. AAS membership data show the members between 18 to 24 years in 2003 comprise ~60% women. The young members of the Society provide an opportunity to follow a cohort through the astronomy pipeline, to document their career paths and why they chose them.

Acknowledgements: FB thanks Rachel Ivie and Kevin Marvel for data as well as Margy Kivelson, Meg Urry, Stefanie Wachter and the CSWA for discussions on this issue. ❖

Websites

Presentations at Women In Astronomy II - **http://www.aas.org/~cswa/WIA2003.html**
American Institute of Physics Statistical Division - **http://www.aip.org/statistics/index.htm**
Denise Denton's Advance program - **http://www.engr.washington.edu/advance/**
CSWA Astronomy Survey 2003 - **http://www.grammai.org/astrowomen/stats/**
NRC Study of Undergraduate Education - **http://www.nap.edu/catalog/10711.html**
Committee on the Status of Women in Physics - **http://www.aps.org/educ/cswp/index.html**
CSWP Site Visits - **http://www.aps.org/educ/cswp/visits/index.html**
Sheila Widnall's AAAS Presidential Address - **http://web.mit.edu/aeroastro/www/people/widnall/aaas_pres.pdf**

References

Denton, D., *The Washington ADVANCE Program*, Women In Astronomy II, Pasadena CA, 2003

Hoffman, J.L. and K.B. Kwitter, *Results from the 2003 CSWA Survey of Astronomical Institutions*, Women In Astronomy II, Pasadena CA, 2003

Ivie, R., and K. Nies, *Women in Physics and Astronomy 2003*, Women In Astronomy II, Pasadena CA, 2003

Ivie and Stowe, *1997-8 Academic Workforce Report*, American Institute of Physics, 1998

Marvel, K., *AAS Membership Demographics*, Women In Astronomy II, Pasadena CA, 2003

McCray, R.A., R. L. DeHaan, and J.A. Schuck, (Eds), *Improving Undergraduate Instruction in Science, Technology, Engineering, and Mathematics: Report of a Workshop*, National Academy Press, 2003

National Research Council, *Transforming Undergraduate Education in Science, Mathematics, Engineering and Technology*, National Academy Press, 1999

National Science Board, *The Science and Engineering Workforce: Realizing America's Potential*, National Science Foundation, 2003

Rosser, S. Review of *Women in Science: Career processes and Outcomes* by Y. Xie and K. Shauman, Science, 302, 1506-7, 2003),

Seymour, E. and N.M. Hewitt, *Talking of Leaving: Why Undergraduates Leave the Sciences*, Westview Press, 1997

Tobias, S., T*hey're not Dumb, They're Different: Stalking the Second Tier*, Research Corp., Tucson AZ 1994

Tobias, S., *Revitalizing Undergraduate Science: Why Some Things Work and Most Don't*, Research Corp., Tucson AZ 1992

Widnall, S.E., AAAS Presidental Lecture: Voices from the Pipeline, *Science*, 241, 1740-1745, 1988

Xie, Y., and K. Shauman, *Women in Science: Career Processes and Outcomes*, Harvard University Press, 2003

Sheila Widnall is Institute Professor of Aeronautics & Astronautics and of Engineering Systems at MIT. She has served as secretary to the Air Force and as a member of the Columbia accident investigation board. The following is an excerpt from her 1988 AAAS Presidential Lecture which was published in Science (v241, pp1740-5, 1988) and is reproduced with permission of the AAAS and the author. The editor has selected passages that discuss three gender surveys of students made in the late 1980s (please contact Fran Bagenal if you know of a more recent survey). For a full version see ***http://web.mit.edu/aeroastro/www/people/widnall/aaas_pres.pdf***

Voices from the Pipeline

by Sheila Widnall

Photo from Widnall collection

Sheila Widnall

Graduate Student Surveys

Several recent surveys of male and female graduate students preparing for scientific and technical careers were carried out at Stanford University (*8*) and at the Massachusetts Institute of Technology (MIT) (*9, 10*). In addition to quantitative detail about differential attitudes, expectations, and experiences of these students, the wealth of comments from students provides considerable insight about the process of graduate education as seen from the student's perspective.

In the Stanford study, graduate students in medicine, science, and engineering were surveyed, with a 54% return rate for a total number of 627 students. The results were presented only for the combined group. The major conclusions of this work were that the women were indistinguishable from the men in the objective measures of preparation, career aspirations, and performance in graduate school. They differed significantly in their perceptions of their preparation for graduate study, in the pressures and roadblocks that they experienced, and in the strategies that they developed for coping with these pressures.

Graduate students at MIT were surveyed both by the Graduate School Council (*9*) and by the presidentially appointed Committee on Women Students Interests (*10*). Both surveys covered all of the departments in the institute. More than 1600 questionnaires institute-wide were returned in the first survey. Within the School of Science, 476 student questionnaires were returned in the second survey. The MIT surveys reinforced the conclusions of the Stanford survey. In addition, in both the MIT surveys, the results differed widely across departments, including responses to questions focused on the academic environment for women students. Whether these distinctions are due to differences in fields, the different percentage of women students in the various departments, the personality of the departments, or specific policies and practices that a department uses to provide information and academic guidance to the students is not clear. However, the survey results indicate that for departments with a poor environment for women students, a few specific measures might lead to a considerable improvement for all students.

Nationally, women enter graduate school at about the same rate as men relative to their presence in the B.S. pool (2). The career aspirations of women in the Stanford survey were the same as those of the men. Objective measures of their academic achievements and potential indicate that the entering women students were as qualified for graduate work as the men. Men in the Stanford survey scored slightly higher on the math section of the Graduate Record Examination, whereas women scored higher on both the verbal and the analytical portions of the exam and had a higher undergraduate grade point average. The grade point averages of the male and female students as graduate students were essentially the same (8). As a group representative of only a fractional percentage of the cohort of females of their age, statistics of large groups or preconceived ideas about their specific interests, attitudes, aptitudes, or commitments cannot be applied.

Graduate Education and Research

Education can be seen as a continuum, a progression from the development of career-related skills in a preset curriculum to the achievement of autonomous professional capabilities. However, it is at the graduate level that the student begins to function as an independent scientist–indeed, that is the purpose of graduate education. Ideally, graduate education should proceed from an explicit set of tasks–acquiring advanced skills through courses, preparing for and passing a set of qualifying exams to demonstrate mastery of one's field, and carrying out technical work under the close supervision of a faculty adviser–to the development of independence in the student. During this process the faculty gradually begins to remove the props supporting the student and to place more responsibility on the student for problem formulation, evaluation, execution, and defense. Ideally, as the process occurs, the student has access to a variety of structured professional experiences designed to enhance self-confidence and build independence. These experiences include opportunities to present and defend research results in regular and productive group meetings, to evaluate and criticize the work of peers, to formulate and carry out research tasks of increasing importance, to participate in dialogues and debates about scientific and technical issues, and to discuss future career plans as they relate to current interests and activities.

Faculty members often do not make these latter parts of the educational process explicit to the student. Much of the stress of graduate education results from lack of student understanding of this hidden agenda. Students who duck such professional experiences because of a lack of self-confidence or because they find them painful are deprived of an important component of the graduate experience. Although they may be successful in achieving a Ph.D., they may not be equipped to take full advantage of the next set of career possibilities, and they are unlikely to be recommended by their mentors for important opportunities in their profession. Attention to how women and minorities are affected by and respond to this hidden agenda will be valuable in developing strategies to allow them to achieve their full potential.

These familiar facts of life of graduate education are at the heart of much of the stress felt by all graduate students. However, the white male students benefit from the self-reinforcing confidence that "they belong." The self-identification with the predominantly white male faculty reassures them that graduate school is a step on the way to a productive career in science, and that many others with whom they can identify have done it before them. For women students, minority students, and many foreign students, the environment is not as reinforcing. Their acceptance by the system is not automatic. Results from the Stanford survey (*8*) indicate that 35% of the men compared to 24% of the women were confident of "making it" in their chosen field; 62% of the men, but only 51% of the women, anticipated an academic career.

Results from Student Surveys

In the various student surveys, students commented on their personal experiences in graduate school. Most of the comments were complaints about their current system. There were subtle differences in the responses of men and women. The men most often expressed anger, even rage, at the system and suggested ways that it should be changed, whereas the women more often described the effect that the current system had on them and expressed feelings of frustration and discouragement. For example, the following comments were made by students from the same department when asked what hindered their graduate education (*10*):

1) From a man: "The absolute insensitivity of the professors, department, and university to the inevitable depression experienced by young scientists when their research doesn't work so well. The … university's … willingness to ignore all graduate students but the … top 10% elite."

2) From a woman: "Despite denials, as a woman in … science … I had something to prove–and yet the most difficult part about it is that I don't know what it is or how to prove it. There is just the knowledge that I have at least one more test to pass than my male counterparts. Or maybe it's one more test to pass daily."

As revealed by student surveys, the issues affecting minority, foreign, and women students are related to their differences from the majority, their feelings of powerlessness, and feelings of increased pressure and isolation. For example, significantly larger percentages of women students than men students in both the Stanford and the MIT studies reported that the environment was detrimental to their health (*8, 10*). In the Stanford survey, 23% of the women versus 9% of the men reported that they thought they were on the verge of a nervous breakdown. The data on minority students are too sparse to draw any conclusions, but it is likely that graduate school is an extremely stressful environment for them.

Women students are not a minority at the undergraduate level in our colleges and universities. Yet the effect that education has on them sets the stage for their minority presence in graduate school. Studies indicate that the self-esteem of women students is lowered in college, while the self-esteem of male students is raised.

The Illinois Valedictorian Project (*11*) was a study that followed a group of 80 students (46 women and 34 men) who had graduated in 1981 at the top of their high school classes. The group continued their high academic performance, with the women earning a final grade point average of 3.6 and the men an average of 3.5 for their college years. In spite of this objective record, when this group was surveyed at several points in their educational careers concerning their self-estimate of intelligence relative to their peers, the results shown in Fig. 4 were obtained. The shift of self-esteem to lower ratings is quite evident for the women students. At the end of high school the groups were quite comparable, but females suffered a significant loss of self-esteem in the sophomore year of college. At the senior year of college, no women had a self-estimate in the highest category, whereas 25% of the men did, even though the grade point average of the women was higher than that of the men. In contrast, the self-esteem of the men increased slightly during the college years. Even though women in science

Continued on page 22

Voices *continued from page 21*

have degree completion rates above those of the men and carry on to graduate school at about the same rate, these results suggest that they arrive at graduate school with some uncertainty about their abilities, even though their academic records and test scores are equivalent to those of the men.

A second trend noted in this study (*11*) was the lowering of career ambitions by the women students. The researchers linked lowered career ambitions in part to the unresolved dual-career problem: that is, the student's uncertainty about how to combine career and family responsibilities. One of the most effective antidotes for these uncertainties about career goals was the opportunity for successful professional experiences: independent research, professional employment, opportunity for interaction with graduate students, and the support and encouragement of a faculty mentor. Most women scientists of my generation can probably point to a single individual who was supportive at the undergraduate level without whose encouragement they would not have gone to graduate school.

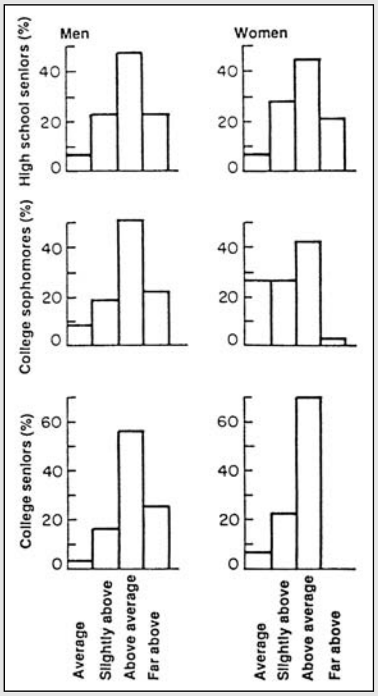


Figure 4: Self-report of intelligence as compared to peers (*11*).

Without such opportunities a woman student may carry through with excellent performance in classes but be unsure about her actual potential as a professional. She may also develop the well-documented "imposter" syndrome with its accompanying fear of eventually being "found out." This insecurity shows up in several ways. In spite of objective data indicating that women in graduate school have academic backgrounds comparable to their male peers, a significantly higher percentage of women in the Stanford survey (*8*) reported that their preparation for graduate school was inadequate. In the MIT survey (*10*), women students reported more difficulty in acquiring research skills. Whether these self-assessment reports are true or represent women students who downgrade their capabilities is not clear from the data. The reports could also be related to the student's interactions with her research adviser. In some cases the process of acquiring research skills may be unconsciously set up for women to fail: women may be given too much help on easy skill-building programs (because it is perceived that they cannot do the work alone) and then are left to flounder on the more difficult problems. In the Stanford survey, 82% of the men and 73% of the women reported being satisfied with their programs; 72% of the men and 61% of the women reported that they believed they were progressing as well as other students (*8*).

For the women students themselves, as well as the departments in which they study, some serious attention to these issues is warranted. Objective discussions between adviser and student about the academic background required to undertake certain lines of research should take place, and ways to fill in any weak areas should be identified. Discussions of the expectations of the department for graduate student performance beyond the classroom, identification of objective criteria that should be met on the way to independent research, and some specific attention to methods of acquiring research skills are suggestions to deal with these issues.

Studies of objective evaluations of the potential and the accomplishments of women give quite discouraging results. Such studies in which male or female names are applied to résumés, proposals, and papers that are then evaluated by both male and female evaluators consistently show that the potential and accomplishments of women are undervalued by both men and women, relative to the same documents with a male attribution (*12-15*). I believe that graduate admissions officers are aware of this and attempt to correct for it in the admissions process, but I would be surprised if individual, hard-pressed faculty were immune from this behavior.

Lower expectations by an adviser, whether conscious or unconscious, are quickly perceived by the student. This perception may occur more often with women students, who need additional feedback because of their tenuous position. The student surveys show that women meet less frequently with their research advisers; a smaller percentage of women than men meet weekly; a larger percentage of women than men report meeting rarely with their advisers. Also, more women report that these interactions with faculty do not provide helpful feedback on their research progress. There seem to be qualitative differences in the type of feedback that some women students are looking for. To quote one woman from the MIT survey (*10*): "My adviser tells me whether it's right, not whether it's important." Women reported less frequently than men that they felt free to disagree with their advisers or that their ideas were respected by their advisers (*8*). The issue of barriers to effective communication needs to be examined by both advisers and their women students.

Many faculty socialize extensively with their graduate students through sports and informal get-togethers and may unintentionally leave out their women students or even suggest that they are unwelcome at such gatherings. Women students often conclude that this is a direct reflection of the quality of their research (*10*). Perceived lowered expectations lead directly to a loss of self-esteem and over time to a lower performance–a self-fulfilling prophecy. Women students give their advisers a great deal of power in assessing their ability, and women are apt to internalize and validate their perceptions of this assessment.

On all of the questions in the Stanford survey designed to elicit the level of self-confidence in the academic setting, the women students scored consistently, and in some cases alarmingly, lower than the men: 30% of the women versus 15% of the men questioned their ability to handle the work; 27 versus 12% found criticism difficult to accept; only 30% of the women versus 57% of the men felt confident speaking up in class; and 33 versus 9% feared that speaking up would reveal their inadequacies (*8*). In view of the importance of the hidden agenda that uses structured professional experiences to elicit independence in the student, some significant fraction of the women students is less equipped to seek out, to engage, and to profit from these experiences. Explicit attention to structuring positive professional experiences for all graduate students will improve the environment for women students.

In the Stanford survey, more women (20%) than men (6%) reported never having had major responsibilities within their research group (*8*). In both the Stanford and MIT surveys, women reported less opportunity to publish, or less frequently being the first author on publications (*8, 10*). However, these results differed across departments, with the most encouraging results obtained in those departments that had high percentages of women students.

Environmental Issues

Women graduate students report being subject to inappropriate treatment by faculty and student colleagues. Inappropriate treatment in the context of graduate school is any treatment that emphasizes the student as a women first and a student second. It is any treatment that stresses the social nature of the interaction rather than the professional or educational nature (*12-16*). Many women students report the necessity to continually fend off such inappropriate behavior in order to be allowed to concentrate on the professional issues of graduate school. This continual need to respond to such treatment can seriously interfere with the self-esteem and productivity of women graduate students (*15*).

Even today, there are still a few faculty members in science and engineering who publicly, or in discussions with faculty colleagues, take the position that women do not belong in graduate school. These individuals are at the least tolerated and seldom publicly challenged by their colleagues. Female graduate students quickly become aware of such feelings; although such actions cannot be attributed to an entire department, one wonders how such behavior can be tolerated in a university environment. It is particularly unfortunate if the individual involved would otherwise be the most appropriate adviser for the student on the basis of the student's research area.

Studies of group meetings involving men and women reveal that women are at a disadvantage with respect to male norms in groups (*12-16*). Women are interrupted by men much more frequently than are other men. A woman's contributions are often ignored or attributed to one of the men in the group. Many women students report discomfort at the combative style of communication within their research groups. Studies of men and women in group situations reveal differences in their modes of communication and tension in their intersexual interactions (*12-16*). Men often feel comfortable with a communication style that seeks to reduce one of the protagonists to rubble in the course of a scientific discussion. After the storm is over, they quickly forget about the incident. For many women this style of interaction is unacceptable, either as giver or receiver. A woman student may take weeks or months to recover from such an interchange, and it may contribute to a permanent loss of self-esteem. Women report that a process in which points are won only at the expense of putting someone else down is to them an unacceptable mode of scientific debate. They are looking for a mode of interaction that is other than a zero-sum game.

Women students report being much less satisfied with the information available from departmental channels on issues such as the structure of qualifying exams and financial support policies. They also report not being as well integrated into the student network (where copies of past exams, for example, can be obtained). For access to such resources, the acceptance of women students as colleagues by their male peers is essential.

A disturbing percentage of women in the MIT survey reported that their gender is a significant barrier to access to academic resources (*10*). The quantitative results ranged from 16 to 30% across the various departments in the School of Science. This was true even in those departments where women students had high self-esteem. In the Stanford survey, 13% of the women (compared to 1% of the men) reported that the sex of their adviser had a negative impact on them; 40% of the women (compared with 30% of the men) reported having had some negative experience with faculty members, whereas 20% of the women (versus 7% of the men) reported experiencing some form of discrimination (*8*).

Continued on page 24

Voices *continued from page 23*

Women students have raised some fundamental issues about the quality of graduate education for all students. The continued drop-off in the percentage of B.S. degree holders who eventually attain the Ph.D. may be related directly to the current environment seen by graduate students. If we are to escape the projected dramatic decrease in the number of graduate students, some improvement in graduate education for all students is necessary.

With respect to improving the environment for women students, an increased sensitivity on the part of faculty to the seriousness of women as professionals and the willingness of faculty to structure the research environment to enhance self-esteem and provide positive professional experiences are the most important features. A willingness by the faculty to publicly challenge professional colleagues who make prejudicial or inappropriate remarks about women students would improve the climate. An effort by faculty to make the group interaction a positive-sum game for all students, while being no less insightful and scientifically critical, would enhance the graduate experience. The positive comments on the student surveys by both men and women reported the beneficial effects of such an educational environment. Such suggestions, if more widely followed, would improve the professional and human climate of our graduate schools for all students. ❖

2. " *Professional women and minorities: A manpower data resource service*" (Commission on Professionals in Science and Technology, Washington, DC, ed. 7, 1987).
8. L. T. Zappert and K. Stanbury, "*In the pipeline: A comparative analysis of men and women in graduate programs in science, engineering, and medicine at Stanford University*" (Working Paper 20, Institute for Research on Women and Gender, Stanford University, Stanford, CA, 1984).
9. " *Report of the 1986 graduate student survey* " (Academic Projects and Policies Committee of the Graduate Student Council, MIT, Cambridge, MA, November 1986).
10. "*Survey of graduate students*" (Presidential Committee on Women Students Interests, MIT, Cambridge, MA, 1987).
11. K. Arnold, "*Retaining high-achieving women in science and engineering*," AAAS Symposium on Women and Girls in Science and Technology, University of Michigan, Ann Arbor, July 1987.
12. "*The classroom climate—a chilly one for women*" (Project on the Status and Education of Women, Association of American Colleges, Washington, DC, 1982).
13. ` *The classroom climate revisited: Chilly for women faculty, administrators, and graduate students* (Project on the Status and Education of Women, Association of American Colleges, Washington, DC, October 1986).
14. R. M. Hall and B. R. Sandler, "*Out of the classroom: A chilly campus climate for women?* " (Project on the Status and Education of Women, Association of American Colleges, Washington, DC, 1984).
15. J. K. Ehrhart and B. R. Sandier, " *Looking for more than a few good women in traditionally male fields* " (Project on the Status and Education of Women, Association of American Colleges, Washington, DC, January 1987).
16. M. P. Rowe, "*Hypotheses about the effects of subtle discrimination at work and in education*" (MIT, Cambridge, MA, 1986).

The Astronomical Community Loses a Rising Star

by Patricia Knezek, Joannah Hinz, and Meg Urry

The astronomical community as a whole, and those of us who worked with Beth on STATUS in particular, were deeply saddened to hear of the death of Dr. Elizabeth (Beth) Holmes on Tuesday, March 23, 2004. She was a dedicated and passionate astronomer, as well as an advocate for women's issues. Despite her youth within our field, she was already making a mark.

Beth was an undergraduate at MIT, majoring in physics and participating in the Undergraduate Research Opportunities Project with Professor Chuck Counselman. She developed her senior thesis under Dr. Heidi Hammel analyzing Hubble Space Telescope images of the planet Neptune. Her contributions included measurements of the locations of discrete cloud features, from which she derived zonal wind speeds. Beth also helped with an analysis of color-dependent reflectivity of Neptune's atmosphere based on Voyager 2 spacecraft imaging. She graduated with a S.B. in 1995.

Beth then attended graduate school at the University of Florida. She worked with Professor Stanley Dermott on a variety of topics involving numerical dynamical modeling and was awarded a NASA Graduate Student Researchers Program (GSRP) from 1997-2000. Her work included numerical simulations of dust particles released from Plutinos and Kuiper Belt objects trapped in the 3:2 mean motion resonance with Neptune, searching COBE DIRBE data for observational signatures of the Kuiper disk, and numerically modeling background zodical dust clouds to study asymmetries caused by the presence of planets. She also extended her research to the observational realm in a collaboration with Dr. Harold Butner at the Heinrich Hertz Submillimeter Telescope, surveying nearby main sequence stars for excess emission indicative of circumstellar material at 870 and 1300 microns. Her Ph.D. thesis, entitled "Signatures of Planets: Observations and Modeling of Structure in the Zodiacal Cloud and Kuiper Disk", was completed in 2002.

After completing her thesis, Beth joined the Spitzer Space Telescope MIPS team at JPL as a National Research Council Associate. There she assisted with the planning of early release and guaranteed time observations to survey the circumstellar environments of nearby F, G, and K stars in collaboration with Dr. Charles Beichmann and Dr. T. Velusamy. She also continued to construct dynamical models of debris disks in preparation for comparison with incoming

Beth Holmes
June 24, 1973 - March 23, 2004

Photo by Samantha Lawler

Spitzer data. At the time of her death, she was modeling the debris disk of Fomalhaut as seen by the MIPS instrument.

In addition to her active research career, Beth was quite interested in women's issues in science. She had been an associate editor of STATUS, the CSWA bi-annual magazine, since 2003. She volunteered her services to the CSWA while still a graduate student, after a CSWA reception at the AAS. Her enthusiasm and commitment were much valued. She had recently expanded her involvement with STATUS to authorship, and her article on "The Postdoc Perspective on the Women in Astronomy II Conference" ran in the January 2004 issue of STATUS (see **http://www.aas.org/~cswa/status/Status_Jan04.pdf**).

The astronomical future looked very bright for this talented young scientist. She has been described as "an up and coming star" in the astronomical community, and she will be sorely missed by all of us who had the pleasure of knowing her. ❖

Laura Lopez graduates from MIT in 2004. Her undergraduate thesis is "A Continuum Model of the High Resolution X-ray Spectra from the Relativistic Jets in SS 433". She is excited about starting graduate school at Penn State in the fall and working on the Chandra Deep Field and AGN science.

Diversity in Astronomy and Astrophysics: A Study of Tenured and Tenure-Track Faculty at PhD-Granting Departments

by Laura Lopez

Laura Lopez

Professor Donna Nelson of the University of Oklahoma has made surveys in various science and engineering fields (the Nelson Surveys are available online at: **http://cheminfo.chem.ou.edu/faculty/djn/diversity/top50.html**). Last year, when Professor Nelson was visiting MIT, we conducted a faculty demographic study of all the United States astronomy and astrophysics Ph.D.-granting departments. We polled all 56 departments offering astronomy Ph.D.s. We requested disaggregated data on race/ethnicity, gender, and rank of all tenured and tenure-track faculty conducting astronomy-related research. Every surveyed department except two chose to participate. This study was the first to rigorously assess representation and rank of females and minorities within astronomy faculties across the United States.

The findings indicate 12.2% of astronomy professors are female, and 20.2% of assistant professors are female. Of all astronomy professors 90.6% are Caucasian, and 80.1% of all professors are Caucasian male. Of astronomy professors 6.8% are Asian, nearly half the Asian faculty representation in physics. Hispanics comprise 1.38% of astronomy faculty, 1.08% are Black, and 0% are of Native American descent.

To learn the full results of our survey, please read the June issue of SPECTRUM, the AAS Committee on the Status of Minorities in Astronomy newsletter. To be put on the mailing list, download issues or read material online see **http://www.vanderbilt.edu/csma/newsletter/spectrum.htm**. ❖

The American Geophysical Union awards the John Adam Fleming medal in honor of "original research and technical leadership in geomagnetism, atmospheric electricity, aeronomy, space physics, and related sciences." It is one of the highest honors of the AGU. The 2003 Fleming medal was awarded to Professor Christopher T. Russell of the University of California at Los Angeles for his "unequaled record of scientific accomplishment in space physics," notably in the field of planetary magnetospheres and their interactions with the solar wind. The citation for his award can be found at ***http://www.agu.org/inside/awards/russell_ct.html****. We have chosen to reproduce his response in STATUS because of his advocacy that more honors be awarded to women scientists.*

A Prize Response

By Chris Russell

Chris Russell

"I am very pleased to receive this award named for a fellow geomagnetician, John Adam Fleming, who was once very influential but is now somewhat less known. For those interested in his career, I refer you to an excellent biography written by Merle Tuve and published in the National Academy's Biographical Memoirs in 1967. Fleming was "an indefatigable worker and a prolific writer." He served as General Secretary of AGU for a full solar magnetic cycle, or 22 years. In addition to geomagnetism, the Fleming Medal recognizes work in atmospheric electricity, aeronomy, space physics, and related sciences. Awards, however, are often defined more by the recipients than any other factor. The 35 men who have received this award before me include some of the most brilliant I have ever met. They also include the only scientist who has ever hit me, but that story is better left for another time.

"I have many people to thank for helping me during my career, but none more than my mother, who at 89 years of age is still a very bright woman. She, like myself, was strongly attracted to science, but her father would not allow a young girl to pursue such a career. She was directed to study to be a secretary. Fortunately times have changed, and last year in the United States more doctorates were awarded to women than men.

"We have many excellent female scientists in our profession, and I have been lucky enough to work with some of the best. Among these have been Marcia Neugebauer, Joan Feynman, Margaret Kivelson, and Janet Luhmann. But where are names like these in the list of AGU Fleming medalists? Where are the Carols, Nancys, Patricias, Michelles, and Peggys? It is time for AGU awards to become more inclusive. One way to begin this process is to rename some of the awards. For example, Marcia Neugebauer would be just as appropriate a role model for today's scientists as John Adam Fleming was for scientists in the 1960s.

"In closing, let me stress that I am very grateful for being selected for this award, but I would have also been quite happy to wait while some of my equally deserving colleagues were honored." ❖

-C. T. Russell, University of California, Los Angeles

NOTICES

A SECTION OF STATUS

She Figures 2003

She Figures 2003 is a handy reference tool that will enable policy-makers to review the latest European and national trends for both highly qualified women and men. It presents descriptive statistics and indicators for EU Member States and Associated Countries as well as explanatory texts and methodological notes. As such, the document signals a new era in the availability of sex-disaggregated data on human resources in the European Research Area. *She Figures 2003* finds overall healthy growth rates in the numbers of researchers in the Higher Education sector in nearly all Member States and Candidate Countries, and among industrial researchers in Portugal, Spain, Finland, Italy, Lithuania, Cyprus, Norway and Hungary between 1998-2001. However, government research institutions and industry lost research staff, both women and men, in about half of the Associated countries during the same period. The percentage of research posts held by women is half as much in the Business Enterprise Sector (15%) than in the Higher Education Sector (34%) or Government Research institutions (31%). Between 1999 and 2000, the average percentage of women researchers for the EU-15 increased slightly by 2% in the Higher Education Sector (from 32% to 34%).

Why are women so under-represented? Level of qualification can no longer be regarded as an excuse for the under-representation of women as researchers. However, the statistics presented in *She Figures 2003* suggest that appropriately qualified women may be less likely than their male counterparts to opt for research posts in R&D, and are more likely to prefer technical occupations. Since today's graduates are tomorrow's scientists, *She Figures 2003* examines the graduate statistics for 2001 and has discovered that the EU-15 average for women graduates from doctoral / Ph.D. education has just reached 40%. In all of the Associated countries except Hungary, the Czech Republic and Norway, more than 40% of graduates from these advanced programs are women.

In six out of the 14 Member States presented in *She Figures 2003*, there is still less than one woman for every ten men in the top echelons of academia. From 1999-2000, there was a slight overall increase from 11.6% to 13.2% women in the top grades of University staff, but in Austria and the Netherlands only 6% of senior academic staff are women. Just 3% of the top layer of academic staff in engineering sciences in Portugal are women and this figure is as low as 1.7% in Austria. Men are overall three times more likely than women to reach the most senior levels. Only 6.4% of women academics reach these top grades in the EU, whereas the same recognition is reserved for as many as 18.8% of men. Women also appear to be blocked from membership of scientific boards. In eight out of 15 Member States and in nine out of 11 Associated Countries, less than 25% of the members of scientific boards are women. These figures are as low as 6.6% in Luxembourg, 10.3% in Belgium and 11.8% in Austria. This calls for an urgent review of recruitment strategies and appointment procedures.

The full report (plus extensive appendices of data) can be found at:

http://europa.eu.int/comm/research/science-society/women/wssi/publications_en.html ❖

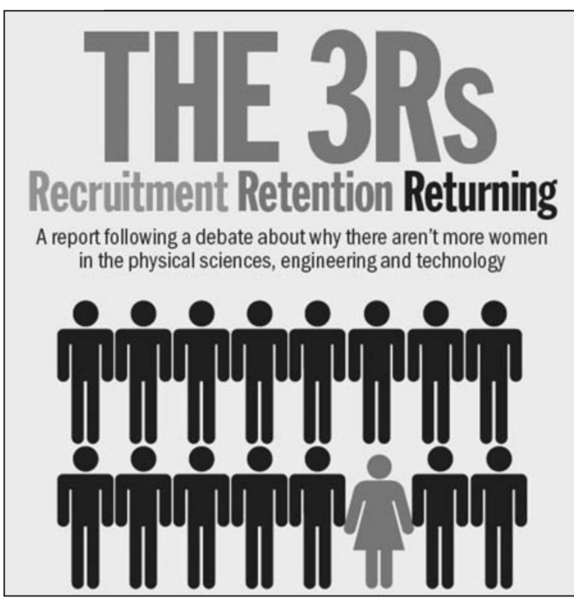
Notices *continued from page 27*

Gender Differences in the Careers of Science, Engineering, and Mathematics (SEM) Faculty

In response to a formal mandate from Congress, the Committee on Women in Science and Engineering (CWSE) and the Committee on National Statistics of the National Research Council will conduct a study to assess Gender Differences in the Careers of Science, Engineering, and Mathematics (SEM) Faculty, focusing on four-year institutions of higher education that award Bachelor's and graduate degrees. The study will build on the Academy's previous work and examine issues such as faculty hiring, promotion, tenure, and allocation of institutional resources including (but not limited to) laboratory space. The study will: 1) update data analysis of a previous CWSE study; 2) collect and analyze currently available departmental data on careers of women faculty, and; 3) survey a small sample of university departments.

The study, sponsored by The National Science Foundation, had its first meeting in late January. A Final Report will be issued at the end of the project in approximately 18 month. The committee comprises:

Dr. Sally Shaywitz (Co-Chair) is Professor Pediatrics at the Yale University School of Medicine.
Dr. Claude Canizares (Co-Chair) is the Associate Provost and Bruno Rossi Professor of Experimental Physics at MIT (perhaps better known to STATUS readers as an x-ray astrophysicist and PI of a Chandra instrument).
Dr. Linda Abriola is Dean of Engineering and Professor of Civil and Environmental Engineering at Tufts University.
Dr. Jane Buikstra is a biological anthropologist and archaeologist and is the Leslie Spier Distinguished Professor of Anthropology at the University of New Mexico.
Dr. Alicia Carriquiry is Associate Provost and Professor of Statistics, Iowa State University.
Dr. Ronald Ehrenberg is the Irving M. Ives Professor of Industrial and Labor Relations and Economics at Cornell University and Director of the Cornell Higher Education Research Institute.
Dr. Joan Girgus is Professor of Psychology at Princeton University and Special Assistant to the Dean of the Faculty for matters concerning gender equity.
Dr. Arleen Leibowitz is Professor of Policy Studies in the UCLA School of Public Policy and Social Research.
Dr. Cathleen Synge Morawetz is Professor Emeritus at the Courant Institute of Mathematical Sciences, New York University.
Dr. Thomas Taylor is Roy A. Roberts Distinguished Professor at the University of Kansas.
Dr. Lilian Shiao-Yen Wu is a research scientist and Program Executive for University Relations, IBM Corporate Technology. ❖



3Rs: Recruitment, Retention and Returning

On International Women's Day (8 March 2004), a new report, explaining how the UK can stop the female brain-drain in science, engineering and technology (SET), was published by the Institute of Physics and the Daphne Jackson Trust. Are equations and electric circuits really too much for women to cope with, or is there another reason why there are so few women with careers in science, engineering and technology? Do we have a problem in the system, which excludes almost 50 per cent of the population from these professions? The report, The 3Rs: Recruitment, Retention and Returning makes practical recommendations that will help reverse current trends. This report stems from a debate held in September 2003 with panelists prominent in science based industry, academia and politics from the UK, Europe and the USA. It targets SET businesses and industries who could and should be making their work environments more flexible and 'gender neutral' to suit modern society.

The report gives four key recommendations.

1. Hard facts get results: gender data from UK industry are needed to provoke industry into addressing imbalance in the system.
2. Industry and business leaders – men as well as women – need to be committed to developing measures to tackle gender imbalances for action to be effective.
3. Plugging the leaky pipeline: action is needed at all points where people can opt in or out of science, engineering and technology careers.
4. Children should know more about the range of science and technology based careers, so that they do not rule them out unknowingly.

The Institute of Physics and the Daphne Jackson Trust want these points to be taken on board by the Government and industry. It is not only the women who are losing out, but industry as well – when fully trained women leave the sector early in their careers their expertise is wasted. It currently costs £51,000 (about $80,000) to put a physics student through a three year postgraduate degree, but if they do not stay in the sector, the investment does not pay off.

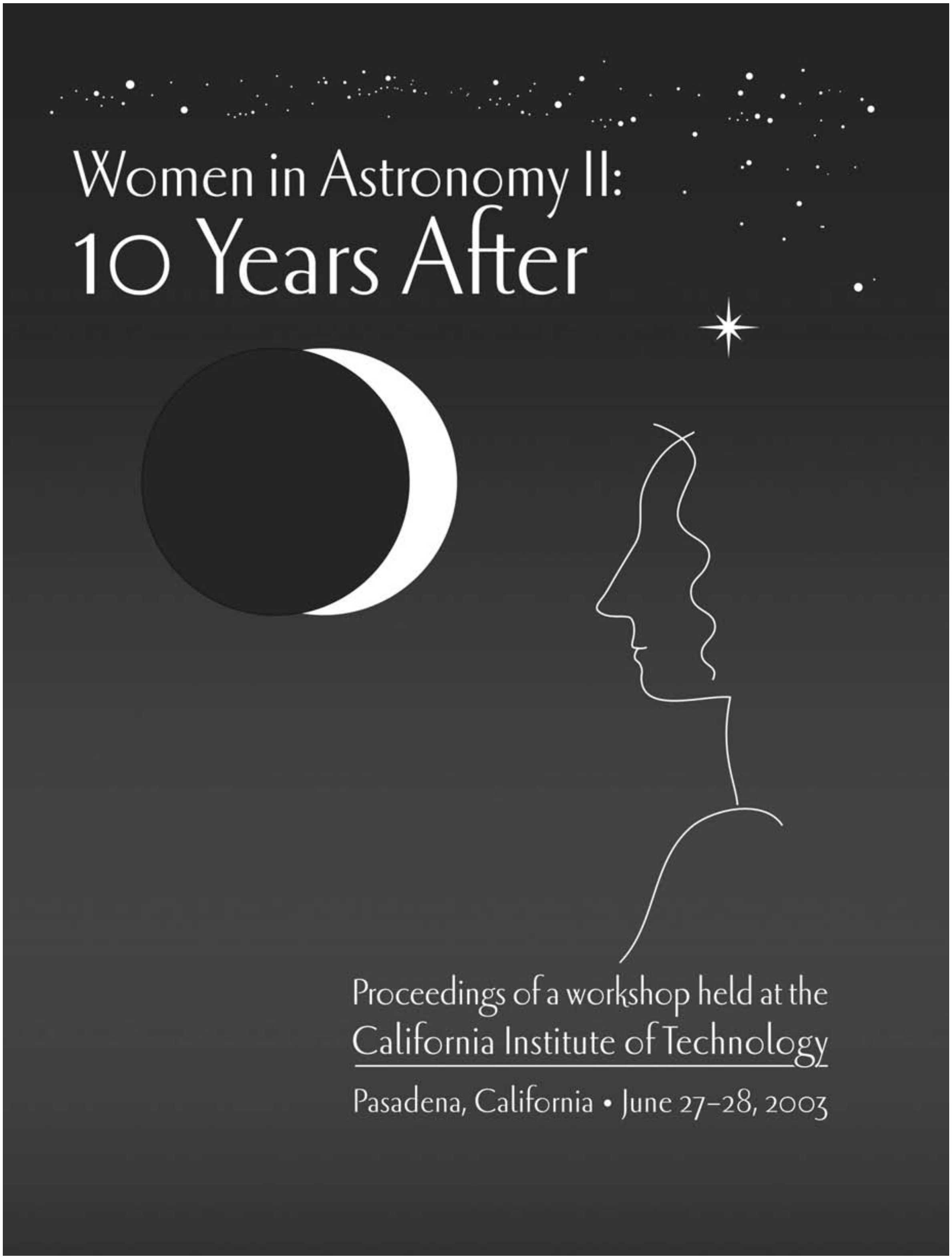
Julia King, chief executive of the Institute of Physics, said:

"The Institute of Physics recognises the difficulties facing women in physics and related careers, and we are doing our best to change attitudes and to create a better working environment for all physicists, both female and male. Science and engineering-based companies need to look at their own situations, as they are losing out on highly capable women who feel that this sector cannot fulfil their needs. Industry has the power to make a difference."

The fourth recommendation stresses that children need better careers advice, as they do not realise what can be on offer to them if they study the physical sciences. For example, the current editor-in-chief of *Good Housekeeping*, Lindsay Nicholson, is an astrophysics graduate and a successful journalist. She feels that her astrophysics degree was the ideal way to start off her career. She said:

"I don't know why girls allow themselves to be herded into arts subjects. You can enjoy reading books, going to galleries and the theatre whatever subjects you studied at school or college. But if you don't have a good grounding in maths and science so many of the wonders of the physical world - indeed the universe - will remain closed to you. What's more, the training you get in how to think rigorously imparts a degree of confidence that stays with you all your life. Much of my success has been because I am able to express thoughts and ideas with far greater clarity than my arts-trained colleagues."

The full report *3Rs: Recruitment, Retention and Returning* can be downloaded at **http://diversity.iop.org/news/index.html.** ❖



The artwork of Ann Rebecca Feild will be featured on the cover page of the proceedings of the 2003 Conference on Women in Astronomy. The proceedings are currently being edited by Meg Urry. The contents will reflect the key talks at the conference, on current demographic data (Marvel, Ivie), why women leave science (Seymour, Tobias), what barriers face women generally (Valian), how to change institutions (Denton, Huang), legal considerations (Rolison, Fishman), and diversity in a broader sense (Stassun, Ortega). ❖

"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

We received this letter from a young woman we met recently at a meeting on women in science. She started out interested in physics but found herself increasingly discouraged. Some years after leaving graduate school, she realized that the lack of role models or other women students, and the predominant male culture, had made her feel isolated and in the wrong place. Armed with this insight, she has returned to physics and is herself working to improve the environment for other women. With the author's permission, we are reprinting her letter with names elided to preserve anonymity. Other young women may recognize this woman's experience and be inspired by her perseverance, and perhaps men will understand more about how their female colleagues might feel. The message that you can reverse or at least overcome the discouragement is particularly hopeful.

♀ I have a somewhat unique perspective in that I am one of those women who left the field. I received my BS from [large high-quality public university] in 1990 and continued in their PhD program for two years. I left a very unhappy person, hoping never to step inside a physics department again. Eventually, I settled into a job as [a scientific editor]. I worked for several years at [computer company] and then began editing some physics articles. My passion for physics resurfaced, albeit very tentatively. With a therapist I began to explore the idea of returning to physics. We looked at why I left the first time, and how I might address the problems I had if I were to return. In the process several things became clear to me. I was much more affected by my minority status than I had realized. Without being fully conscious of it, I had been highly discouraged to see so few women as role models, and to be stuck with groups of men who interacted in ways I didn't find comfortable. I was discouraged by the fact that no one in power was stepping up to say we need more women in physics.

I was also discouraged to see the types of women who did succeed, those who could put their heads down and concentrate, put the issue of women in science "on a back burner", and plow through with "determination." I'm not like that at all. The impression I got was that since I'm a sensitive person who can't ignore my surroundings, I must not be as determined as other women and therefore not belong in physics. I have heard this advice before, and each time it is like a big neon sign saying "You can't be yourself and succeed in physics!"

So how did I make a comeback? First, I decided that the message I'd received was wrong. Instead, I realized I could be sensitive and be a great physicist. Second, I learned how to address my feelings by following a path opposite to the advice I'd been getting. Instead of putting my head down, I work on the issue of women in science on a daily basis, reminding myself I belong here, and the things that make women feel uncomfortable in our department are wrong. True, I don't have time to make big changes, but I can address little things every day. I erase the derogatory comments about women on the hallway chalk board. I comment when colleagues say inappropriate things. With short conversations in the hall, I help raise their awareness bit by bit. I stick up for myself, and by saying people like me belong here, I gradually convince myself that I do. I joined AWIS [American Women in Science], where I can go to meetings occasionally and see a diverse group of women succeeding in scientific careers. I tell myself that it is OK to be different from other women in physics, and to concentrate on what we have in common, a passion for science.

In short, I recognize how the system affects me, and I consciously take measures to reverse those effects. After taking many refresher classes over the last three years, I successfully entered the PhD program at [another large high-quality public university] last fall.

That makes it sound easy, but of course, it's a continuing challenge. Being older, married, with a child actually helps. I've got the benefit of some life experience, a strong support network, and much more self confidence than I had at 22. I look forward to being a role model someday for people like myself, who don't seem to fit well in our current system, whether it's because of their personality, gender, ethnicity or age. I think it's important to recognize that the methods women have used to succeed in the past are the same ones that didn't work for those of us who left. If we'd like to increase the diversity of the field, we need to explore a much wider variety of techniques for making it through the system. ❖

Send your "Notes" to
bagenal@colorado.edu

STATUS Editorial Team

Left to Right: Lisa Frattare, Meg Urry, Pat Knezek, Fran Bagenal, and Joannah Hinz

Photo Collage by Steve Bartlett

STATUS June 2004

American Astronomical Society
2000 Florida Avenue, NW, Suite 400
Washington, DC 20009

First-class
Postage Paid at
Washington, DC
Permit No. 1725