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Analysis of Institutional Data

Final Report

to the

CfA Gender Equity Committee

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Overall project overview

The present report constitutes the third and last major component of a large-scale study of gender equity at CfA under the auspices of the CfA Gender Equity Committee (GEC). Reports were already submitted for the first two components. The first element was a web-based employee survey, designed by the committee and analyzed by Gerhard Sonnert. The second were extensive face-to-face interviews with employees, conducted and analyzed by Wendy Roth.

The GEC study thus used the approach of methodological triangulation, in which multiple methods are employed. Whereas such a triangulation certainly involves a considerable expense of time and money, its advantage is that each method has unique strengths that mutually complement each other.

For instance, the unique strength of the face-to-face interviews was that employees could, in their own words and in considerable detail, share their own work experience at CfA, their satisfactions and dissatisfactions. On the other hand, only a small sample of CfA employees could be part of this interviewing project. At the cost of loss of detail, the web-based survey made it possible to cast a wider net. It gave all employees the opportunity to participate; yet, of course, not all took it, so that there was, as in all surveys, the potential problem of response bias. The present report now typically analyzes <u>population</u> data--basic information, kept by the administration or in other databases. about all current employees. Hence there is no response bias, and a fairly precise picture of the institutional situation can be achieved. The limitation of this method is, of course, that only very basic information, and not everything one would like to have, is available. Nonetheless, the basic objective information of the kind collected in this part may be a useful complement to the more subjective satisfactions and dissatisfactions reported by CfA employees in the survey and the interviews.

Introduction

This report has five parts. It covers (1.) employment and rank, (2.) extra compensation, (3.) work space, (4.) publication productivity, and (5.) external funding. With the exception of publication productivity, which was obtained from the ADS database, the data came from the administration, as described in more detail in the respective parts. It is important to note that the administrative data cover <u>SAO employees only</u> (whereas the largest part of the publication productivity analysis also includes HCO employees). Attempts were made to obtain also HCO data, but these were unsuccessful, owing to existing confidentiality policies.

The first three parts apply to employees in general, whereas the other two cover specifically scientists.

Two important points need to be made: one about issues of statistical analysis, and the other about the basic approach to gender differences.

Issues of statistical analysis

Because we are dealing here not with sample data, but with population data, this is not a typical case for the application of inferential statistics. Inferential statistics engages in a lot of "significance testing" that gauges the probability that a difference (e.g., a gender difference) found in a sample also exists in a population. Some differences found in sample data might thus be considered non-significant, because there is a high likelihood of them being an artifact of sampling.

In a situation when precisely measured population data are used, differences are simply what they are. However, significance testing—which corresponds to the "error bar" approach familiar to many at CfA[1]--is still applied here as a gauge for the importance of existing differences. By treating the population as a sample of itself, “error bars” (confidence intervals) or, equivalently, p-levels can be used to identify gender differences that might be considered substantial.

When using the transmitted dataset to explore longitudinal issues, e.g., those connected with length of service, age, or time since the highest degree was obtained, we come up against two analytical problems. First, information about their employment history is available only for those employees who are still currently employed at CfA. In other words, people who once worked at CfA but left are out of the picture. Ideally, however, a statistical analysis would look at complete cohorts of people hired in specific time periods and follow their employment history through the years to capture information about dropping out. The available data thus potentially bias conclusions about gender equity. For instance, even if the career progress among the “survivors” showed no gender difference, there is still the possibility that a gender difference might exist in differential rates of leaving CfA. Nonetheless, the available data present a valuable picture of gender differences among the present CfA workforce.

Second, the available "snap-shot" (cross-sectional) data do not allow unequivocal conclusions about longitudinal processes, because time and cohort effects are potentially confounded. For instance, a graph showing average increase in grade over time at CfA does <u>not</u> depict how a group of employees moves through the ranks, but it rather presents a snap-shot of the current situation at CfA,

<u>Issues of interpretation: What does "gender difference" mean?</u>
There are two approaches to this question. One is to take gender differences at face value and do simple comparisons of the relevant variables by gender. In this way, a lot of gender differences can be detected, but the down-side is that people are likely to point to other variables that could also explain the observed differences. The other approach is what could be called a residual approach. It first takes account of the other factors that also bear on the variable in question. Only then, after controlling for the other factors, gender is entered into the analysis to see if it makes an <u>additional</u> difference. The counterargument against this approach is that the seemingly extraneous control variables might in fact be influenced by underlying gender differences. In this report, I typically report both the straight gender differences and, where possible, also gender differences

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[1] A significance level of $p<.05$ for a measured difference is equivalent to Zero lying outside an error bar around the measured difference of two standard errors on either side.

that remain after controlling for other variables.

1. Employment and rank

1.1. Data

The following is an analysis of data transmitted by SAO HR, reflecting the status of May 2005. (h data file was created on 31 May 2005.) The file contains data for 601 individuals, 403 of whom are men and 198, women.

1.2. Some basic characteristics of employees by gender

Here are some variables, broken down by gender, that describe some basic characteristics of the CfA workforce.

Age

For both men and women, the median birth year was 1959. The average birth year, however, was earlier for the men than for the women (1957.0 vs. 1959.6), owing to a heavy representation of men among the oldest employees. The range of birth years for men went from 1911 to 1981, whereas the women's range was 1930 to 1984.

Agency

23% of the men, but only 10% of the women were federal employees, the rest being Trust employees. Differentiating by the employees' educational background, one finds that, among the men, the group with a doctorate has the highest percentage of federal employees (32%). Among the women, those with a doctorate are also more likely to be federal employees (16%) than women employees, on average; but the group of Master's degree holders has an equally elevated level (17%).

Work schedule

A higher percentage of men than of women work full-time (91% vs. 84%). Conversely, women are more likely than men to work part-time (12% vs. 5%). In absolute numbers, thus, more women than men (23 vs. 19) work part-time, although men outnumber women 2 to 1 as CfA employees.

Only 13% of the female part-timers have a doctorate, but 42% of the male part-timers do, which fairly reflects the respective educational attainments of female and male CfA employees in general. In terms of grade, however, almost half of the small group of male part-timers is at grade 15 (43%, compared to 18% of all male CfA employees), whereas the top grade among female part-timers is 14 (13%, compared to 14% of all women at grades 14 and 15). The average age of the male part-timers is 63 years, compared to the women's 48 years.

These findings appear to indicate, as seems plausible, that part-time employment at CfA tends to occur at different life and career stages for men and women. Whereas among the men, older employees predominate, for many of whom part-time is probably a way of transitioning from work to retirement, the group of women part-timers contains a larger proportion of younger employees for many of whom, presumably, the choice of part-time employment is precipitated by family responsibilities, such as raising a family.

1.3. Occupational structure

The HR data contained a detailed occupational code for each CfA employee. 62 different codes were present among the 601 employees. As might be expected in a Center for Astrophysics, the largest occupational group, consisting of a quarter of the employees (150), were the "astronomers/astrophysicists"--and one might add to them the 46 physicists (the third largest occupational group). The second largest occupational group after the astronomers/astrophysicists consisted of IT specialists (134). Fourth came the "administrative specialists/officers/division administrators" (45), followed by the mechanical engineers (24) and staff assistants (20).

Not surprisingly, men and women at CfA tend to work in different jobs. 30% of the men were astronomers/astrophysicists and 10% were physicists, whereas the corresponding percentages for the women were 14% and 2%, respectively. 6% of the men, but only 1% of the women were mechanical engineers. By contrast, higher percentages of female than of male employees were administrative specialists/officers/division administrators (16% vs. 3%) and staff assistants (which was an entirely female domain--10% vs. 0%). 26% of the women and 20% of the men were IT specialists.

It is instructive to look at occupational groups by the employees' educational background. Among the 115 employees without Bachelor's degrees (62 men, 53 women), the women clustered in administrative positions, whereas the men cluster in what could be described as "blue collar" occupations. 19% of the women were administrative specialists/officers/division administrators (men: 2%), 19% were staff assistants (men: 0%), and 9% were secretaries (men: 0%). By contrast, 23% of the men in this educational grouping were IT specialists (women: 11%), 16% of the men were engineering technicians (women: 2%), and 10% were electronic technicians (women: 4%).

Among the 185 Bachelor-level CfA employees (109 men, 76 women), a similar pattern emerged to some extent. 21% of the women were administrative specialists/officers/division administrators (men: 7%), 13% were staff assistants (men: 0%). 13% of the men were mechanical engineers (women: 0%). However, this level was dominated by the IT specialists, and remarkably little gender difference was found here. 44% of the men with a Bachelor's degree were in this occupational code, as were 42% of the women

Among the 91 Masters-level CfA employees (54 men, 37 women), women again clustered into the administrative specialists/officers/division administrators category (16%; men: 6%). Mechanical engineering contained a higher percentage of men than of women (11% vs. 3%) and electronic engineering was an exclusively male occupation (13% vs. 0%). Again, the occupation of IT specialist included similar percentages of the male and female employees at the Masters level (men: 31%, women: 27%).

Among the 210 doctoral-level CfA employees (178 men, 32 women), the genders' occupational distributions were the most similar. 84% of the men as well as of the women were astronomers/astrophysicists or physicists (This percentage includes 21%

physicists among the men and 9% physicists among the women, however.) Most of the remaining women were IT specialists (13%), whereas the remaining men were spread over several different occupations.

In sum, employees with a doctorate—both men and women--were the most homogeneous group in terms of occupation. They were highly likely to work as scientists in the broad area of astrophysics. Among the Bachelor-level employees, the preponderance of the IT specialist occupational designation, in which men and women were represented in roughly equal percentages, created a certain gender similarity, but among the other educational groups, the gender distributions diverged markedly in ways typical for the larger society, with the women being concentrated in administrative and the men being concentrated in technical jobs.

1.4. Grades

As is typical for most institutions, there is a huge gender difference at CfA in terms of the occupational hierarchy. Women tend to be found in the lower echelons; and men, in the higher echelons. Chart 1.1 of grades by gender indicates that, in all grades up to 9 (with the exception of Grade 3), women outnumber men. In all higher grades, men outnumber women. Grade 9 is the modal grade for the women, whereas Grade 14 is the modal grade for the men. Men also have a higher median grade (13 vs. 11). Excluding employees without grade (i.e., senior employees), the gender difference in average grade is also about two full grades (men: 12.3, women: 10.2).

Insert Chart 1.1 here

Chart 1.2 of the gender composition of grades shows that, in general, the proportion of men rises as one looks at higher grades.

Insert Chart 1.2 here

Grade and step

Within each grade level, there are various steps, ranging from 1 to 10, in the dataset. To create a combined grade and step measure called GRADESTEP, the step was reduced by 1, divided by 10, and then added to the grade. Employees with no grade (i.e., senior employees) were excluded.

$$Gradestep = Grade + \frac{Step - 1}{10}$$

Men were found to have a higher average GRADESTEP than did the women. The difference was more than two GRADESTEPs (men: 13.0, women: 10.9).

It may be insufficient to look at this result in isolation, as there are obvious determinants of GRADESTEP other than gender. We now consider two key predictors of GRADESTEP: the educational level of the employee and the length of service.

1.5. Educational level and GRADESTEP

Education plays a large and still increasing role in shaping a person's work and career prospects in our society. The SAO HR administration keeps very detailed information about the employees' educational level. For the purpose of this analysis, we collapsed this information into five large categories: high school (or less than high school diploma, or terminal occupation program), some college, Bachelor's, Master's (or similar degree), and doctorate. The most poignant gender imbalance occurs at the doctorate level, which is the modal level for the men, but a relatively rare level among the women. The modal educational level for the women is the Bachelor's degree.

Insert Chart 1.3 here

Looking at the gender composition of the educational levels, one realizes that the three lower levels are relatively balanced, but that fewer than 20% of the employees with a doctorate are women.

Insert Chart 1.4 here

Now we look at educational level and gradestep in conjunction. As the following table shows, education is indeed a powerful predictor of gradestep. (Note that the educational levels were further reduced from 5 to 4 by combining "highschool" and "some college.)

Educational level and average gradestep

	men		women		
	N	GRADESTEP	N	GRADSTEP	Significance (p)
Highschool	62	10.6	53	9.3	0.016
BA	109	12.4	76	10.3	<0.0001
MA	54	13.7	36	12.2	0.001
Doctorate	138	14.2	26	14.1	n/s

At each educational level, men have attained a higher average grade than have women. The gender gap is largest among the Bachelor-level employees, where it reaches two full grades. By contrast, the gap is smallest and statistically non-significant among the CfA employees with a doctorate. This group also is fairly homogeneous in terms of their actual jobs (most of them being scientists in the broad area of astrophysicists).

1.6. Time and GRADESTEP

The second main predictor of grade is duration of employment, or some similar measure of time. An employee tends to be promoted over time, so that the longer-serving employees would tend to have higher grades.

The men have spent a slightly longer time at CfA than did the women, on average. The median year of hire is 1995 for the men, 1997 for the women. The average year of hire is 1991.8 for the men, 1993.2 for the women. This difference was too small, however, to reach statistical significance. The following charts present the time of hiring for all current CfA employees and for male and female employees separately. (Note: The date of 12/31/2099, which occurred several times. was set to missing value.)

Insert Charts 1.5 and 1.6 here

In addition to duration of employment, the following time variables were used. For 28 employees, the employment starting date at SAO was different from the regular starting date. A second variable (Time at CfA 2) was created in which that different starting date was used for those 28 employees. Analyses for this new variable were run in parallel with the regular duration of employment variable. As one might expect, the differences in the results for these two variables were negligible. Hence the results of the analyses run with this variable are not reported here.

A meaningful variable is time since degree, because this indicates a certain standing in one's profession that is likely to translate into GRADESTEPs. For instance, someone who is hired 15 years after obtaining his or her doctorate might have an unusually high GRADESTEP in relation to his or her time of service at CfA. Finally, we also used age as a predictor.

The following table gives the ranges of the time variables used in the analysis.

Ranges of time variables by educational levels (in years)

	Time at CfA	Time at CfA2	Degree age	Age
Highschool	0-46	0-46	n/a	23-78
Bachelors	0-39	0-39	0-48	21-78
Masters	0-41	0-41	2-55	22-81
Doctorate	1-48	1-43	1-57	29-94

(Notes: The variable "Time at CfA2" is explained above. There was an anomalously high frequency of the degree year of 2000 among employees below Bachelor's degree. I set those to missing values.)

The simplest and much preferred way of analyzing data including this kind of time-related variables is by linear regression (ordinary least squares regression). This technique fits a straight trend line (y = a + mx) to the data, where a is the intercept, m is the slope, and x is the time variable. However, inspection of the CfA data revealed that this is not the most suitable method in most cases here[2], because the grades do not appear to increase linearly over the course of a CfA career. Rather, they appear to rise quickly at first but then to reach a plateau.

Hence a non-linear growth function of the following type was fitted for each of the four major groups of employees according to educational credentials:

$$Gradestep = I + b_0(1 - e^{-b_1 x}),$$

[2] The exception was that linear techniques were appropriate for age as the independent variable.

where I is the lowest grade found for members of the particular group (I = 3, for Highschool and Bachelors degrees, I = 7, for Masters, and I = 9 for doctorates); x is the independent time variable (e.g., years of CfA employment); b_0 determines the upper limit of the function; and b_1 determines the shape of the function. The coefficients b_0 and b_1 thus indicate the height of the plateau of GRADESTEP achievement and how fast this plateau is reached, respectively.

1.7. GRADESTEP models

The following tables contain information about the coefficients b_0 and b_1 of the estimated growth equations. GRADESTEP is the dependent variable in all cases. Because, among those employees with a doctorate, the most senior ones are ungraded and thus have no GRADESTEP, an alternate GRADESTEP variable was defined by giving those senior employees the hypothetical "Grade 16." The results for this alternate dependent variable are listed at the bottom of the following tables as "including 'Grade 16'." Selected equations will be presented as graphs. What all these models do is predict GRADESTEP with a time variable--employment duration, degree age, or (in a linear model) age. For each level of educational background, there are three models: one for all employees, one for male employees, and one for female employees. The models differ in the plateau coefficient b_0 and in the steepness coefficient b_1—some more and some less. One might wonder what we should make of these differences. How serious are they? Although we have population-type data, one could treat them as sample data to gauge the relevance of the found differences through inferential statistics (see discussion at the beginning). Each coefficient estimate has a standard error attached to it. That standard error (closely related to "error bars") indicates the variability of the coefficient—the larger the standard error, the more uncertainty about the "real" value of the coefficient. Using those standard errors, t-tests determine the probability that a difference found between coefficients in a sample might not exist in the population, but might be some random artifact of sampling. Conventionally, the threshold is $p<.05$. That is, if we drew 100 samples from a population in which the coefficients are really the same, a p-value of .05 indicates that the observed difference (or a larger difference) would only come up in only 5 of those 100 samples. (See note on statistical tests.[3])

[3] Standard t-tests were used to test the statistical significance of differences between the men's and women's means. The formula applied was $t = \dfrac{m_1 - m_2}{s\sqrt{\dfrac{1}{n_1} + \dfrac{1}{n_2}}}$, where $s^2 = \dfrac{n_1(n_1 - 1)se_1^2 + n_2(n_2 - 1)se_2^2}{n_1 + n_2 - 2}$, and where n_1 and n_2 are the respective numbers of employees in the analysis, m_1 and m_2 are the respective means, and se_1 and se_2 are the respective standard errors.

Employment duration

		N	B0	SE	B1	SE
high school	men	61	**8.81****	0.527	0.376	0.108
	women	49	**6.62****	0.358	1.18	0.698
	Total	110	7.66	0.322	0.537	0.152
BA	men	106	**9.97*****	0.292	0.972	0.204
	women	75	**8.07*****	0.355	0.763	0.184
	Total	181	9.32	0.251	0.746	0.117
MA	men	50	7.1	0.318	0.419	0.127
	women	35	6.58	0.629	0.216	0.07
	Total	85	7.03	0.342	0.268	0.054
Doctorate	men	133	6.15	0.161	**0.243****	0.024
	women	24	5.38	0.338	**0.551****	0.193
	Total	157	6.06	0.152	0.258	0.025
Doctorate	men	172	6.47	0.142	0.233	0.021
including	women	30	6.21	0.373	0.274	0.070
"Grade 16"	Total	202	6.44	0.13	0.236	0.020

Degree age

		N	B0	SE	B1	SE
BA	men	109	**10.59*****	0.28	0.23	0.028
	women	76	**8.63*****	0.39	0.23	0.04
	Total	185	10	0.25	0.21	0.021
MA	men	54	8.37	0.41	0.1	0.014
	women	36	7.24	0.94	0.085	0.028
	Total	90	7.99	0.45	0.093	0.014
Doctorate	men	138	6.24	0.17	0.14	0.013
	women	26	5.88	0.35	0.16	0.037
	Total	164	6.18	0.15	0.14	0.012
Doctorate	men	178	6.72	0.13	0.12	0.008
including	women	32	6.45	0.34	0.13	0.023
"Grade 16"	Total	210	6.68	0.12	0.12	0.008

Notes: SE = standard error. **Bold** indicates significant (two-tailed) t-test for gender difference. ***: p<.001; **: p<.01; *: p<.05. Because of the anomalously high frequency of the degree year of 2000 among employees below Bachelor's degree, this category was excluded from the "Degree age" table.

In all cases, the fitted functions predict a lower GRADESTEP plateau for women than for men. Hence, even controlling for educational background and for time of service (or time since degree), women CfA employees, as a group, attained lower expected GRADESTEPs than did the men.

When considering employment duration as time variable, the gender difference in GRADESTEP plateau was so large as to be statistically significant among the CfA employees without a college degree and among those with a Bachelor's degree. For the former group, the difference was more than two full grades, for the latter group, almost two full grades, as can be seen in the following two graphs.

Insert Charts 1.7 and 1.8 here

The only significant gender difference of the shape coefficient was found for the CfA employees with a doctorate. Here younger women, up to about 8 years of employment duration appeared to do slightly better in terms of gradestep than did the men, whereas at later points the men were slightly ahead.

Insert Chart 1.9 here

It may be important here to note that men with a doctorate were hired on average 6.2 years after receiving that degree, whereas that gap was more than a year larger for women (7.3 years), on average. If one looks at the curve with time since doctorate on the x-axis, the difference in slope shape disappears.

Using time since degree as time variable, the only significant gender difference was found to be the plateau height among holders of a Bachelors' degree.

Insert Chart 1.10 here

When we overlay the graphs for the different educational groups, we obtain the following pictures. (Note that there are no curves for employees without a Bachelors degree on the chart for time since degree, because, as mentioned, most of these data were missing.)

Insert Charts 1.11 and 1.12 here

Including the senior scientists in these analyses at the doctoral level by assigning them a hypothetical "Grade 16" had no dramatic effect. If anything, the gender gap in terms of the GRADSTEP plateaus shrank. Furthermore, the difference in slope coefficients (when looking at employment duration as the independent variable) attenuated.

The careers of men and women with a doctorate (i.e., typically men and women astrophysicists) exhibit fewer gender differences, that is, are more similar to each other than the careers of employees with other educational backgrounds. If one looks for really big gender differences, one has to turn to the employees with no college education or those with a Bachelor's degree.

When looking at employment duration, we see that men without Bachelors degrees "overtake" women with Bachelors degrees in grade step at about an estimated 6 years of service, and then plateau about 0.9 grades higher. Also notice the relatively steep early increase in GRADESTEP for men with Bachelors degrees when considering time since degree.

Finally, here is a look at age as a predictor of GRADESTEP. In this case, a linear approach appeared appropriate upon inspection of the data. In addition to the parameter estimates, the following table includes the proportion of variance explained by the model (R^2) and its square root (the correlation coefficient r).

Age—(linear models)

		N	Intercept	SE	Slope	SE	R2	r
high school	men	62	4.18	1.148	**0.133****	0.0229	0.3594	0.5995
	women	53	7.64	1.525	**0.032****	0.0291	0.0228	0.1510
	Total	115	5.66	0.981	0.087	0.0192	0.1544	0.3929
BA	men	109	6.46	0.769	0.142	0.0178	0.3731	0.6108
	women	76	5.91	0.942	0.115	0.024	0.2382	0.4881
	Total	185	5.74	0.625	0.144	0.015	0.3354	0.5791
MA	men	54	9.02	0.917	0.094	0.0178	0.3473	0.5893
	women	36	7.02	1.337	0.108	0.0262	0.3193	0.5651
	Total	90	8.1	0.829	0.1	0.0162	0.3046	0.5519
Doctorate	men	138	10.52	0.46	0.078	0.0094	0.3334	0.5774
	women	26	9.11	1.264	0.104	0.0262	0.3982	0.6310
	Total	164	10.37	0.429	0.08	0.0088	0.3387	0.5820
Doctorate	men	178	10.50	0.366	0.081	0.0070	0.4316	0.6570
including	women	32	8.73	1.10	0.115	0.0220	0.4785	0.6917
"Grade 16"	Total	210	10.34	0.345	0.084	0.0066	0.4336	0.6585

Notes: SE= standard error. **Bold** indicates significant (two-tailed) t-test for gender difference. ***: p<.001; **: p<.01; *: p<.05.

Especially striking is the result for the prediction of GRADESTEP by age for those employees without college degrees. Here age played very little role for the women, whereas it increased the expected GRADESTEP for the men. For these women, thus, there was little evidence of a career progression, in contrast to the men.[4] Cohort and longitudinal effects are of course confounded here, as in all presented analyses.

Insert Chart 1.13

1.8. Time spent in grade

Whereas most of the available career data are cross-sectional (with the obvious limitations that this type of data entails), the variable "time in grade" provides a small window for glimpsing on the individual employees' career trajectories. (Based on the starting date in a the current grade, which was transmitted in the data file, the time period spent in the current grade [until May 31, 2005] was calculated both in days and in years. Only the latter variable will be reported.)

For the 554 current (as of May 2005) CfA employees (363 men, 191 women) for whom this information was available, the average time in grade was 5.6 years. The median was

[4] This analysis was repeated with full-time employees only, because one might suspect that the higher proportion of female part-time employees had some influence on the findings. In fact, the result was very similar and the pattern remained the same.

4.2 years. Men, on average, were found to have spent more than a year longer in their current grade (men: 6.0 years; women 4.8 years; p=.0041).

Those at grade 15 (the highest grade) also had spent the longest average time (9.4 years) at their current grade, indicating a ceiling effect. This, however, was particularly pronounced for the men, who averaged 10.0 years at grade 15, whereas the few women at grade 15 averaged only 4.0 years.

As was to be expected from the promotional practices at CfA, the time spent in a grade correlated with the employees' step. Those CfA employees at step 10 had spent an average of 8.7 years in their current grade, whereas those with step 1 had been in their current grade for only 1.1 years, on average. here, a ceiling effect of sorts may also be seen in the disproportionate number of employees at the top step (Chart 1.13)

Insert Chart 1.14

Both time periods were longer for men than for women. The men at step 10 had been an average of 9.3 years in their current grade, whereas those with step 1 had been there for 1.5 years, on average. By comparison, the women at step 10 had spent an average of 7.7 years in their current grade, whereas those with step 1 had been in their current grade for only 0.5 years, on average.

2. Extra compensation

The salaries of SAO employees are explicitly and strictly regulated; they are associated with the employees' grades and steps. There are, however, various other forms of compensation, which are the topic of this section.

The following data were transmitted from the SAO HR office: cash awards for four recent years (2001 through 2004) and "time-off" awards during the same years, as well as recruitment bonuses, relocation bonuses, and retention allowances. The transmitted data table again included 601 current (as of May 2005) CfA employees under the purview of the SAO HR office, 403 men and 198 women.

2.1. Recruitment bonuses, relocation bonuses, and retention allowances

These three forms of extra remuneration are extremely rare at CfA. Not a single case of a recruitment bonus can be found in the data. In 5 cases, relocation bonuses were reported, one of which came under federal relocation regulations. In the remaining 4 instances, bonuses ranged from \$1,500 to \$ 10,000, with the mode at \$5,000. All 4 recipients were male. 6 CfA employees (4 men and 2 women) received retention allowances (ranging from 15% to 25%).

2.2. Cash awards

This is a more widespread method of giving CfA employees some extra pay. From 2001 through 2004, 65% of the CfA employees received a cash award. The percentages of men and women obtaining cash awards were near identical. However, if one looks at the size of the cash awards, significant gender differences become apparent. Over the four years, male CfA employees received a total of \$1930, on average, whereas the women received only \$1372, a difference of more than \$500.

In the following, we look at annual cash awards rather than the total amount of the awards over four years to take into account that some employees had not been at CfA during that whole time period. (For example, if an employee was at CfA only during the last two years of the period in question, his or her annual cash award would be calculated by adding the rewards received in those two years and dividing them by 2).

Among those employees who did receive some cash award, the average annual award was \$857 for men but only \$629 for women. If one looks at the whole population of CfA employees (i.e., counting those who received nothing as having a \$0 award), the same kind of gender difference re-appears at a lower level. The average annual award for men in this case was \$553, while for women it was only \$411.

Because the years 2003 and 2004 may have constituted an unusual circumstance in terms of cash awards, this analysis was repeated for the years 2001 and 2002 only. We found that the above pattern was replicated.[5]

[5] From 2001 through 2002, 54% of the CfA employees received a cash award. The percentage was again virtually identical for men and women. Male CfA employees received a total of \$964, on average, whereas the women received only \$693. Among those employees who did receive some cash award, the average annual award was \$1,111 for men, but only \$853 for women. If

Gender is not the only factor influencing the size of cash awards at CfA. A major determinant was grade, with higher grades receiving larger awards (Chart 2.1). (For this chart and in the following analyses, the absence of cash awards is included as a $0 award.) Note: Because of low numbers in certain grades, the grade 7 category includes all employees at grade 7 or lower. Similarly, the grade 9 category also includes employees at grades 8 and 10. (The chart shows the results for the years 2001-2004; an analogous pattern was found for 2001-2002.)

Insert Chart 2.1

As pointed out earlier, women tend to be overrepresented in the lower grades at CfA. The gender difference in the size of cash awards may partly reflect the fact that women's average grades, and thus their average annual salaries, were lower. Indeed, a regression on annual awards that included grade as a control variable made the gender difference virtually disappear (both for the 2001-2004 and 2001-2002 periods).

For the cash awards in the years 2001 and 2002, we also looked at the percentage that the awards represented of the CfA employees' annual salaries. An approximate estimate had to be made because the employees' salaries in the years 2001 and 2002 were not known. Hence, the employees' grade and step information from the year 2005 was used to determine the salary figures in conjunction with the salary table of 2001. This, of course, leads to a slight underestimation of the percentages, owing to promotions that may have occurred in the interim. This bias, however, applies to the whole group of employees; and, because we are interested in potential gender differences among the employees, it can be neglected.

Based on this approach, the highest percentage that awards constituted of an employee's regular salary for the two years 2001 and 2002 was 3.7%. On average, CfA employees received cash awards amounting to 0.7% of their regular salaries. If we only look at those employees who did receive at least one cash award in 2001 or 2002, the corresponding percentage was 1.4%. Gender differences did not reach statistical significance. If anything, the cash awards constituted a slightly higher percentage for the women than for the men (women: 0.8%; men: 0.7%—and considering only recipients: women: 1.4%; men: 1.3%).

Furthermore, when looking at annual cash awards from 2001 through 2004 by broad occupational categories, a dichotomy was found between financial administrators, writers, librarians, and educators, and everybody else, with the former group receiving about half the average annual cash awards of the others. (The same pattern, in attenuated form, was found for the years 2001-2002).

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one looks at the whole population of CfA employees (i.e., counting those who received nothing as having a $0 award), the average annual award for men was $601, while for women it was only $458.

Cash awards were also highly uneven across divisions, but here the picture varies depending on whether one considers the whole period of 2001-2004, or only the years 2001-2002, as can be seen in Charts 2.2 and 2.3. These charts show only divisions for which this analysis included more than 5 employees.

Insert Chart 2.2

Insert Chart 2.3

In this area—as in some others--gender differences are substantial if one simply compares all male and female CfA employees with each other. Once other factors are taken into consideration, these gender differences attenuate or disappear. The question is, of course, to what extent these other factors themselves may be marked by gender inequities.

2.3 Time off

Women got time-off much more frequently than men did. During the years 2001 through 2004, 29% of the female CfA employees and 12% of the male employees were in that category. The average annual time-off award given was 12.0 hours for women and 8.3 hours for men. If we count those who did not receive any time off as having 0 hours time-off, then the women's average annual time-off was 3.5 hours and the men's was 1.0 hours. When one examines the average hours of time-off by birth years, it becomes obvious that, for men, this option is at low levels regardless of their age, whereas it is more variable for women. Those women born in 1960 through 1964 and in 1970 through 1974 showed the largest average amounts of time-off. A plausible explanation might be that many of those women were involved in child raising and/or elder care. Interestingly, among the youngest cohort (those born in 1975 or later), time-off for women is very low, even lower than for the corresponding group of men.

Insert Chart 2.4

Time-off varied with grade, but not in a simple linear fashion. The peak was at grade 7. A relative maximum was again reached at grade 12, and then the numbers generally dropped. In the higher reaches of the job hierarchy at CfA, time-off became an increasingly rare option.

Insert Chart 2.5

Time-off also dramatically varied with division (again, only larger divisions are shown in chart).

Insert Chart 2.6

Even controlling for these factors, a gender difference remained.

Finally, one might wonder to what extent cash awards and time-off awards might be alternatives—in the sense that a CfA employee who receives one kind of award might be less likely tyo receive the other. There was indeed a negative correlation between average annual cash awards and average annual time-off (r=-0.08), but it was small and statistically non-significant. A similar picture emerged from contingency tables of the dichotomous variables of receiving or not receiving any cash award vs. receiving or not receiving any time off. The situation was also similar between the genders in this respect.

3. Work Space

The following analysis of work space is based on the merger of two datasets: a list of rooms and offices including their respective square footage and occupants, and the SAO HR dataset of general employment information. The work space data reflects the situation before the occupation of the new building (CDP). These data also include laboratories and other areas. Furthermore, this analysis applies only to individuals that fall under the SAO HR office. The merged dataset contains information about 601 employees. For the office space analysis, information was available for 523 employees. (Almost all of the missing data are for those employees with duty stations other than Cambridge.)

It seemed reasonable that the space of a given office should be apportioned equally among all its occupants in cases where people share offices. Therefore, two additional variables were created from the original dataset of office occupancy. OCCOUNT counts the occupants in each office. SFPERP, dividing the work space square footage (SF) by OCCOUNT, gives the square footage per person. SFPERP is the dependent variable in this analysis.

3.1. Factors influencing work space allocation

Work space is a scarce resource that is subject to many competing interests, and its allocation can be problematic and even contentious. In our previous survey of CfA employees, work space (or lack thereof) was one of the issues of concern mentioned frequently.

Two possible criteria according to which space is allocated are an employee's position in the job hierarchy (i.e., rank) and seniority (time spent at CfA). One might expect employees who are higher up in the hierarchy as well as those who have been longer at CfA to have been allocated more space, on average.

These aspects can be analyzed with the available data by using GRADESTEP (a combination of grade and step) and PROFAGE (time at CfA) as predictors of a the size of an employee's work space.

Another likely criterion is the job-intrinsic demand on space. Some jobs might require more space than others, owing to special equipment, furniture, machinery, etc., necessary for the work. This is much harder to deal with, given the available data. One way is to examine whether space per person varies across the divisions; another is to look at occupational ratings. The problem with the latter is that we can only analyze large occupational groupings owing to small numbers of employees in most of the ratings. In the following analysis, we use a variable for divisional affiliation as well as a variable that indicates a broad occupational rating.

Moreover, it is probable that historical and idiosyncratic factors influence space allocation, which, however, cannot be taken into account in our analysis.

Finally, the question of greatest interest (for the the Gender Equity project) is whether gender makes a difference for space allocation—most likely in the sense that women at CfA would receive smaller work spaces, on average, than men do.

3.2. Results

Comparing the work space of men and women at CfA, one finds that the men had an average work space of 140.6 sq ft per person, whereas the women had only 112.1 sq ft. An average, thus, the work space of female CfA employees is about 29 sq ft smaller than that of their male colleagues. This difference is statistically significant ($p=.0013$; standard error for difference=11.7 sq ft.).

We now turn to other predictors of work space. Perhaps surprisingly, a CfA employee's grade did not linearly predict the size of his/her work space. Whereas there was no linear trend for the GRADESTEP composite in predicting square footage, an ANOVA treating grade as a categorical variable showed statistically significant results ($p=.0217$, $R^2=.048$). The average square footage by grade is presented in the following chart (where grades held by fewer than 10 persons were deleted).

Insert Chart 3.1

This reveals a somewhat complex pattern. One finds a considerable increase in work space from grades 13 through 15, but grade 13 is also the grade with the least work space per person, on average. Another peak is at grade 11, and the lower grades are essentially flat in terms of average work space per person.

A small, but statistically significant ($p=.0007$, $R^2=.022$) connection was found in a linear regression of work space size on seniority. For each year of employment at CfA, the available work space is expected to increase by 1.4 sq ft, on average. (The inclusion of a quadratic term to capture potentially curvilinear trends did not improve the model.)

(Technical Note: The HR data include a general start of service variable and a variable that indicates the start of employment at SAO for those relatively few employees for whom these two times differ. Thus, seniority can be operationalized in two ways: as the general start of service variable for all employees, or as composite variable consisting of the general service variable for the majority of employees (those who do not have a separate value for start of employment at SAO) and of the start of employment at SAO (for those who do have a separate value on this variable). Almost identical results were found for either variable.)

As to job-intrinsic factors, there were statistically significant differences by division (ANOVA, $p=.0057$, $R^2=.061$). As the following charts show, among those divisions with at least 10 employees, CG and CE employees average about 200 sq ft per person, whereas, on the other end, HEA employees have only slightly more than half that space, on average.[6]

[6] Since HEA is the largest science division in the observatory, HEA office spaces in various jobs were compared with those of the other divisions lumped together (excluding CE and CG). (cont. on next page).

Insert Chart 3.2

The amount of work space was also found to depend on the employee's occupation (ANOVA, $p<.0001$, $R^2=.063$). For this analysis, I formed several large occupational groupings (general administration, financial administration, engineering, writing/education/information, science, IT, support/labor). Whereas administrative employees, scientists, and employees working in writing/education/information have very similar average work spaces (about 130-140 sq ft), the engineers have the largest average work space per person (202 sq ft)--presumably owing to the type of work they do. At the other extreme, the IT personnel has the smallest average work space per person (95 sq ft), which is less than half that of the engineers' (Chart 3.3).[7]

Insert chart 3.3

To reduce the categories present in the variables (which is desirable given the size of N), I formed dummy variables that capture the major variability, as described above. For division, there are now two dummy variables, indicating whether an employee in CE or

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Level of Broad occupation	Level of HEA=1, other=0	N	sfperperson Mean	sfperperson Std Dev
gen admin	0	60	130.9	51.6
gen admin	1	27	111.0	40.4
fin admin	0	16	123.0	36.7
fin admin	1	1	130.3	.
engin	0	7	130.3	36.6
educ/info	0	21	157.3	158.3
educ/info	1	5	86.6	21.8
science	0	114	141.0	126.3
science	1	75	117.1	40.0
IT	0	29	95.2	30.2
IT	1	95	93.6	22.0

Furthermore, gender differences in work space were examined under that broad distinction between HEA and non-HEA (again excluding CE and CG).

HEA=1 others=0	female=1 male=0	N	sfperpers Mean	sfperpers Std Dev
0	0	157	140.6	123.9
0	1	90	120.1	42.0
1	0	128	108.6	35.0
1	1	75	97.7	31.4

[7] There is of course a certain amount of inhomogeneity within those categories. For instance, there are 10 people in CG who all are counted among "administration". The have, in fact, a large average work space (~205 sq ft), but because the whole "administration" group is large, they do not influence the overall average much.

CG, or in HEA, respectively (the variable names are C and HEA). For occupations, two dummy variables indicate whether an employee is in IT or in engineering, respectively. (The variable names are IT and engin.)

The grade scale was simplified by combining grades containing few employees with neighboring grades (i.e., grades 3 through 6 were added to 7; 8 and 10 were added to 9). (Also note that senior employees—those without a grade—serve as baseline in the regressions.)

The following table shows three regression models: Model I including only the control variables, Model II adding a gender main effect, and Model III adding the gender interactions.

Parameter estimates of regressions on work space per person (in sq ft)

	Model I	Model II	Model III
		Gender	
Variable	Controls	main	Gender interactions
Intercept	**169.9**	**170.7**	**171.5**
profage	0.4	0.4	0.2
G7(and less)	**-44.9**	-36.6	5.2
G8/9/10	**-59.2**	**-51.0**	**-62.6**
G11	-24.5	-19.2	1.0
G12	**-60.7**	**-57.2**	**-60.3**
G13	**-72.7**	**-70.4**	**-74.0**
G14	**-59.3**	**-57.1**	**-63.5**
G15	-24.0	-24.1	-21.2
IT	-12.9	-13.5	-17.5
engin	20.4	18.8	21.4
HEA	-14.1	-14.3	-11.0
C	**40.8**	**39.4**	39.0
gender		-13.2	-5.0
iprofage			0.7
iG7 (and less)			-68.7
iG8/9/10			7.2
iG11			-57.1
iG12			-4.3
iG13			10.7
iG14			13.5
iG15			-34.2
iIT			7.5
iengin			9.7
iHEA			-8.1
iC			-28.4
N	508	508	508
R-Square	0.1322	0.1355	0.1565

Bold indicates significance level of at least $p<.05$

Taking all the control variables in consideration, the work place of a female CfA employees is an estimated 13.2 sq ft smaller than that of a comparable male. This difference does not quite reach statistical significance (p=.1676), but I should emphasize again that this is not an inferential framework. The interactions indicate that the gender disparity is concentrated among employees at grades 7 and below, at grade 11, and to some extent grade 15. Interestingly, no such difference appears at the other grades.

In sum, the work space of female CfA employees is, on average, 29 sq ft smaller than that of the male employees. Taking a number of control variables into account, this difference is reduced to 13 sq ft, but still present.

4. Publication productivity

This section contains a statistical analysis of the publication productivity of the CfA scientists. The data were gathered through an ADS (Astrophysics Data System) search, which was done in three divisions: for SAO scientists (N=196), HCO scientists (N=20), and postdoctoral fellows (N=16).

After detection and deletion of a few double entries, the analyses included a total number of 225 scientists, 36 of whom were women. The group of women was large enough to make meaningful statements about them collectively, but not large enough to split them up into various sub-categories. Note that SAO stipend postdocs and visiting scientists are not included this sample.

The following variables were available: gender, Ph.D. year, number of refereed articles, normalized number of refereed articles (according to ADS), number of citations, normalized number of citations, the number of citations for each of the scientist's five most cited publications, and the normalized number of citations for each of the scientist's five most cited publications. From these variables, the following additional variables could be calculated: annual productivity rate (number of articles divided by years since Ph.D.), normalized annual productivity rate, annual citation rate, normalized annual citation rate, average citations per publication, average citations per publication (normalized).

A second batch of ADS publication data (on the same scientists) was collected to explore whether male and female CfA scientists had different proportions of first-authored papers among all their papers, and whether the proportion of citations of a scientist's first-authored papers among the citations of all that scientist's papers differed by gender.

The publication dataset was merged with the general employment file from SAO HR, so that additional analyses on this subset of scientists became possible. In this merged file, information about publication productivity was available for 193 individuals, 167 men and 26 women. Grade and step information was available for 150 individuals, 130 men and 20 women. A group of senior employees was ungraded (37 men, 6 women). (Time since doctorate was not available in every case, which reduced the number of cases in regressions using that variable.)

4.1. Gender differences

The following table presents the gender differences on the relevant variables, as well as the results of t-tests for the statistical significance of these differences. To start with the overall result that is perhaps most important, none of these gender differences reached the significance level of $p<.05$.

	Men	Women	Differ.	Statistical significance
Professional age	20.9	18.4	2.5	n/s
Number of refereed papers	82.9	70.5	12.4	n/s
Normalized number of refereed papers	27.2	22.7	4.5	n/s
Number of citations	2522	2084	438	n/s
Normalized number of citations	698	573	125	n/s
Number of citations to most-cited paper	285	235	50	n/s
Normalized number of citations to most-cited paper	92	72	20	n/s
Number of citations to 5 most-cited papers	770	662	108	n/s
Normalized number of citations to 5 most-cited papers	233	193	40	n/s
Annual productivity rate	5.6	4.9	.7	n/s
Normalized annual productivity rate	1.9	1.4	.5	n/s
Annual citation rate	130	112	17	n/s
Normalized annual citation rate	37	27	10	n/s
Average citations per publication	27.5	23.0	4.5	n/s
Average citations per publication (normalized)	22.9	20.1	2.8	n/s

4.2. Publication productivity and citations

Sociologists of science have often found a gender gap in publication productivity, with women producing fewer publications than men, on average. In this group of CfA scientists, such a difference was found, too, but it was relatively small. On the variables relating to the quantity of publications—as well as to the quantity of citations--the men, as a group, were somewhat more productive than the women; however, none of these differences reached statistical significance. The same result was found regarding high-profile papers. Both in terms of the number of citations a scientist's single most cited paper received and of the total number of citations for the five most cited papers, the men had higher average numbers, and the same was found for the normalized variables. Again, however, these differences did not reach significance.

It is important to take into account that the women scientists at CfA are of a younger professional age, on average, than their male colleagues. In this respect, the average difference between the genders is about 2.5 years. It may therefore be more meaningful to compare variables that control for time (e.g., annual productivity rates or annual citation rates). The men were found to produce an average of 5.6 articles per year; the women had a lower average output per year (4.9 articles), but this difference was not significant. The same picture was found for the normalized productivity rate and for the citation rates. Thus, controlling for professional age, the women as a group still had somewhat lower numbers, but all these differences were again statistically insignificant.

There is a huge variability in publication behavior among CfA scientists, which is not distributed in the shape of a normal curve. Rather, a few CfA scientists have been putting out an enormous stream of publications (thus driving up the averages), a larger group of CfA scientists have been steady producers of a more modest output volume, and a few others have published close to nothing at all (or, at least, nothing showing up in the ADS database). For instance, for the CfA scientists, the number of published articles was found to range from 631 to 0. These substantial individual differences in publication output were, however, quite unrelated to the scientist's gender. In any case, the measured differences in average publication productivity between the two genders did not reach statistical significance.

4.3. Quantity and quality of publications

In interviews, conducted in an earlier study[8], the theme emerged that women scientists would tend to favor a high quality-low quantity approach to publishing, whereas men scientists would try harder to maximize the quantity of their output. This appeared to be a potential explanation of the gender productivity gap. And that earlier study also found that, among academic biologists, the women had a higher number of citations per published articles than did the men.

This led to the questions: To what extent is publication quantity and publication quality related among CfA scientists? And are there gender differences in this respect? As a measure of publication quantity, the average annual publication productivity was used. As a measure of publication quality, the average scientific impact of the published articles was used—i.e., average citations per publication, calculated as the number of citations received divided by the number of articles published.

A small negative correlation was found between annual publication productivity and citations per published article (-.10), but this correlation did not rise to statistical significance (p=.16). Essentially the same result was found for normalized variables (r=-.06; p=.42). When looking at these correlations separately for each gender, all correlations again were small and non-significant.

Another way of examining potential relations between publication quantity and publication quality is the following: Using median splits on the two variables, a two-by-two table can be constructed, which contains the four cells: high quantity-high quality, high quantity-low quality, low quantity-high quality, and low quantity-low quality. The first number in each cell is the percentage of people in that cell, the second number is that percentage for men only, and the third number is that percentage for women only. None of the results was statistically significant.

	low quantity	high quantity
low quality	All:26/ men:25/ women:33	All:24/ men:24/ women:25
high quality	All:24/ men:25/ women:14	All:26/ men:26/ women:28

An analogous analysis was made for the normalized variables of annual publication productivity and of citations per published article. The results were, on the whole, similar. If anything, quantity and quality appeared to go somewhat together, but that was

[8] Sonnert, G., with the assistance of G. Holton (1995). Gender Differences in Science Careers: The Project Access Study. ASA Rose Book Series. New Brunswick, NJ: Rutgers University Press.

not significant. The analyses for the genders separately were also similar to those for the non-normalized variables.

Thus, publication quantity and publication quality were not significantly related among CfA scientists. And there were no significant gender differences in this respect. If anything, there was a relative dearth of women in the low quantity-high quality cell, but this, again, was statistically non-significant.

In sum, on all the studied variables relating to publication productivity and citations, the male CfA scientists, as a group, slightly outdid the female CfA scientists. However, none of these differences rose to the level of statistical significance. Publication quantity and publication quality also seemed rather unrelated, among both men and women.

One contributor to the absence of statistically significant findings is the relatively small number of female scientists; others are the high variability and high skewness in the data distributions.

4.4. Types of authorship

The female CfA scientists were found, on average, to have been first authors of 35.5% of all their published papers. The men were first authors of only 28.4% of all their published papers, on average. This difference of about 7% is statistically significant ($p=.0204$, in a two-tailed t-test). On average, 32.5% of the citations to a female CfA scientist's work cited papers of which that scientist was the first author. The corresponding figure for the men was 27.6%. That difference of about 5%, however, did not reach statistical significance. Women scientists at CfA may have fewer opportunities, or may be less willing, to attach themselves to research projects for which they do not carry the primary authorship responsibilities.

The proportion of first authorship among all published papers was not related to the number of papers published. It was, however, negatively related to the total number of citations that this scientist's work received. This correlation was small, but statistically significant ($r=-.17$, $p=.0105$). Moreover, there was a marginally significant negative relationship between the proportion of first-authorship citations among all citations and the total number of citations ($r=-.13$, $p=.0521$). Whereas these relationships were weak for the men, they were stronger for the women (papers: $r=-.31$, $p=.0659$; citations: $r=-.34$, $p=.0414$). Apparently, the rewards in terms of citations were more sensitive to the authorship pattern for women than for men CfA scientists.

In other words, CfA scientists—and especially women scientists--who published a particularly large fraction of their output as second (or later) author had particularly many citations to their work. Similarly, having a particularly large fraction of citations to one's papers that were not first-authored tended to go with having a particularly large number of citations overall. This might again be a function of the scientist's seniority. In addition, one might look at whether highly cited papers in astrophysics tend to have many authors.

4.5. Publication and employment

The next step was to link the publication data with information about the scientist's professional age, rank, etc.—although the limited number of women scientists will be an obstacle to detailed analyses. A data merge was accomplished by which publication data (collected in 2005) were combined with other information about CfA employees, in particular their grade and step (also collected in 2005). This made it possible to examine the relationships between publication patterns and rank. Note that this merge included only individuals that fall under the HR office (SAO). For the purposes of analysis, grade and step were again combined into the variable GRADESTEP (as explained above).

In this dataset, the CfA scientists' estimated publication output was found to increase by 3.2 publications with each year since the award of the doctorate. This was a sufficiently linear relationship (a quadratic time term was far from significant).

Interestingly, the average publication productivity per year was found to fall by 0.1 publications with each passing year since the award of the doctorate. Note again that these cross-sectional data do not allow us to disentangle to potential effects—a potential life cycle effect of astrophysicists whose productivity may decrease as they progress in their careers, and a potential cohort effect, according to which a younger group astrophysicists might simply publish more than does an older group, on average. Furthermore, there was a significant quadratic time trend (0.00941), which did not add much in terms of curvilinearity, but resulted in a steeper decline, as compared with the linear trend by itself.

As discussed earlier, a linear regression is not the best approach to modeling the increase in GRADESTEP over time, because GRADESTEP increases more rapidly in the earlier career phases and then tends to plateau, as a ceiling effect takes hold. Hence a growth curve might be more appropriate. Nonetheless, the data appear sufficiently linear so as to make linear analyses appear useful for simplicity and ease of interpretation. Therefore, two parallel sets of regressions were estimated: one included the time variable as a linear predictor; the other used the residuals of the following fitted curve as dependent variable,

$$GRADESTEP = 9 + 6.18(1 - e^{-0.141x}).$$

In the following table of regressions on rank, Model 1 includes simply the linear time trend, Model 2 adds Annual Publication Productivity, Model 3 further adds the interaction between Years Since Doctorate and Annual Publication Productivity, Model 4 adds Percent of First Authorships and Model 5 finally adds gender. The Models 2' through 5' correspond to the Models 2 through 5, respectively, but they are regressions on the fitted growth curve rather than regressions using a linear time variable.

Table: Regressions on rank (GRADESTEP)

	Linear Regressions					Regressions on residuals of fitted growth curve			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 2'	Model 3'	Model 4'	Model 5'
Intercept	12.8***	13.2***	13.2***	13.5***	13.5***	0.19	0.08	0.2	0.21
Years since doctorate	0.081***	0.071***	0.063***	0.064***	0.064***				
Annual publication productivity		-0.048***	-0.074***	-0.071***	-0.071***	-0.016	-0.022	-0.021	-0.022
Interaction Years since doct. * Ann. publ. prod.			0.0047*	0.0047*	0.0048*		0.0012	0.0012	0.0013
Percent of first authorships				-0.98*	-0.96*			-0.42	-0.37
Gender					-0.09				-0.20
R2 (%)	41.87	47.84	50.27	52.15	52.20	2.13	2.62	3.59	4.38
N	132	132	132	132	132	132	132	132	132

Significance levels: *<.05
**<.01
***<.001

A striking result of these parallel analyses is that none of the significant relationships detected in the linear analyses hold up in the residual analyses. Evidently, the growth curve to some degree absorbs what otherwise shows up as anomalies in the linear analysis.

Here is a short summary of the findings in the linear analyses. The major predictor of GRADESTEP is academic age—which by itself explains 42% of the variance in GRADESTEP. The other predictors are of lesser importance, although some were found to be statistically significant.

Somewhat counterintuitively, GRADESTEP is negatively correlated to publication productivity (R2=.1808), although the absolute magnitude of the effect is small. An increase of an astrophysicist's average annual productivity by one publication was found to be associated with a 0.07 decrease in the GRADESTEP variable, that is, with a 0.7 step decrease. One should immediately note that GRADESTEP is highly determined by academic age, as reported earlier, and that academic age, in turn, is negatively related to publication productivity, as pointed out above. To some degree, thus, the negative relationship between GRADESTEP and annual publication productivity results from this relationship.

Nonetheless, if one uses a multivariate regression approach, with time and average publication productivity as predictors of GRADESTEP (Model 2), productivity still negatively predicts GRADESTEP. If one considers time, average publication productivity, and their interaction as independent variables (Model 3), all 3 terms are significant predictors, and the resulting regression lines indicate that, among the more senior CfA scientists, high publication productivity is indeed related to a higher GRADESTEP, whereas the opposite is the case among the more junior CfA scientists. (An analogous pattern was found for average citation productivity.)

As one might expect, a high proportion of first-authored publications among all of an astrophysicist's publications was found to predict a lower GRADESTEP, even when controlling for professional age, but no significant interaction between these two predictors was present. In Model 4, for instance, controlling for the other predictors, a scientist with 50% first-authored publications would have a predicted GRADESTEP that is about 0.4 lower—i.e. fours steps lower--than that of a scientist with 10% first-authored publications.

The major result for our purposes—examining the impact of gender—is that, in these analyses, gender did not play any major role (Models 5 and 5').

The following table breaks down annual publication productivity, annual citation productivity, and percent of first authorships by grad and by gender. The table does not contain scientists below grade 13 because of their small numbers in the sample.

Table: Publication variables by Grade and gender

Grade	13		14		15		Senior	
	men	women	men	women	men	women	men	women
Annual publication productivity	3.73	3.46	3.95	3.61	2.17	2.37	5.02	4.16
Annual citation productivity	62.1	65.6	96.3	87.6	71.2	54.3	176.9	202.3
Percent of first authorships	29.5	45.7	29.4	32.5	30.2	24.9	26.3	27.8
N	26	3	38	9	35	4	37	6

Note: None of the gender differences are statistically significant.

Insert Charts 4.1, 4.2, and 4.3

None of the gender differences are statistically significant, owing primarily to the small number of women in each category. Some interpretation may still be warranted because we are dealing here not with a random sample but with the population (of the publishing CfA scientists for whom these data were available).

Among the relatively junior scientists (grade 13), the disparity in the percentage of first-authored publications was the most pronounced, perhaps indicating that those women may have found it harder than the men to connect with collaborators. Among the senior scientists, one might note that the men were somewhat more productive in terms of output, on average, but they had received fewer citations—which is the opposite pattern to that observed among the grade 15 scientists.

5. External funding

This is an analysis of a data file of the external funding obtained by CfA scientists in the Financial Year 2005. The transmitted data contained one line per grant and were transformed to yield the following variables for each scientist: a count of the number of grants, the total award sum, and the average award sum (obtained by dividing the total award sum by the number of grants). Data were available for 103 men and 22 women.

5.1. Number of grants

Only a small gender difference was found in the number of external grants awarded in FY 2005. For both men and women scientists in the file, the average was close to 2 (men: 1.9; women: 2.2).

5.2. Amount of grants

By contrast, huge gender differences were found in the dollar amounts of external funding, with the men receiving much higher sums than the women. The distribution of the amounts of external grant funding was extremely skewed. The largest grant was worth more than $55 million, the next highest grant, close to $8 million, whereas the typical grant was much less. In this situation, averages may not be the best representatives of the distribution's central tendency. Hence, medians will also be reported (as well as non-parametric tests of gender differences). Furthermore, a parallel set of statistics was generated after excluding the PIs of the two huge projects.

All 8 principal investigators who received total funds over $1 million each were men. Mainly because of the few huge grants, the men's average grant total was $923,000, whereas the women's grant total was about $134,000—the men's average grant total thus being about seven times as much as the women's. Similarly, the averages per individual grant were $387,000 for the men and $61,000 for the women. If we look at the medians rather than at the averages, the gender differences shrink considerably, but do not completely vanish. The median grant total for the men was about $115,000, and for the women it was about $78,000. The medians for individual grants were $64,000 for the men and $42,000 for the women.

The exclusion of the two mega-projects reduces the gender gap somewhat, but does not eliminate it.[9]

These dramatic gender differences can be interpreted as such, because we are dealing here with the "population" of all external funding received in FY 2005, rather than with a sample.[10]

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[9] The men's average grant total was now $278,000, as compared to the women's grant total of about $134,000. The averages per individual grant were $155,000 for the men and $61,000 for the women. Because of the nature of the medians, the picture here remained relatively unchanged by the exclusion of the two PIs with the mega –grants. The median grant total for the men was about $110,000 (women: $78,000). The medians for individual grants were $63,000 for the men and $42,000 for the women.

[10] Nonetheless, it might be of interest that these huge differences do not quite reach statistical significance—but the numbers get closer on the non-parametric Wilcoxon test (p=.11 for total

5.3. Inclusion of non-recipients

If we take the group of employees with a doctorate (178 men and 32 women) in the SAO HR file as an approximation of those who could have obtained external funding, we can expand the transmitted file of funding recipients by adding an appropriate number of rows filled with zeros for the funding amount. In this new dataset, the average number of grants received was 1.1 for the men and 1.5 for the women.

Because 69% of all women with a doctorate, but only 58% of all men with a doctorate, had external funding in FY 2005, the gender comparisons become more favorable for women in this larger dataset. Now the average total funds were $534,000 for the men and $92,000 for the women. The averages per individual grant were $224,000 for the men and $42,000 for the women. The comparison of medians changes substantially, owing to the larger percentage of men without funding—now the median for total grants is higher for the women ($42,000 vs. $31,000), and, for the individual grants, the medians are about even (women $22,000; men: $20,000).

Hence, women CfA scientists appeared to be somewhat more likely than the men to have at least some external funding, but the men were heavily represented among the recipients of high volume grants.

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funds, p=.058 for average funds) than on the parametric t-test (p=.15 for total funds, p=.09 for average funds). The exclusion of the two extreme cases, attenuates the non-parametric results, but strengthens the parametric results.