Human Detectors:
A Scientific Approach to Increasing the Numbers of Women in Physics

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Carnegie Mellon University School of Computer Science

Top Ranked Computer Science Program

- Entering freshman class 1995
  Acceptance rate 25.7%
- Entering freshman class 2001:
  Acceptance rate 12.4%

Number of applications rose and
Admissions criteria remained high
average SAT-M ~ 760

But there were some changes:

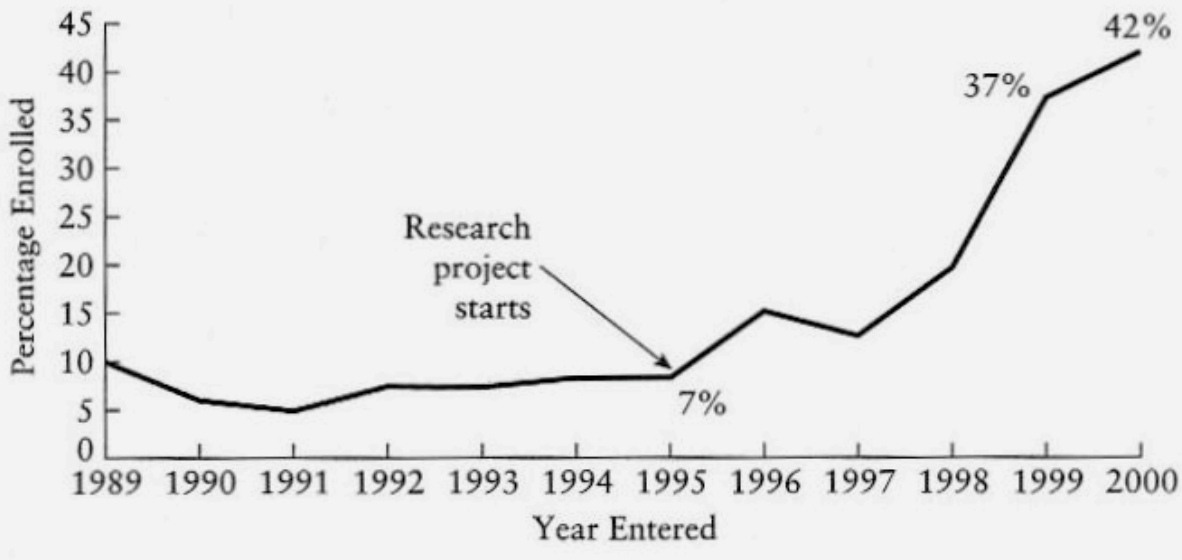


Figure 8.1
Enrollment trends for women entering the School of Computer Science

7% (1995) $\Rightarrow$ 42% (2000)

Margolis & Fisher 2002

Retention rates also improved

(for both men and women)

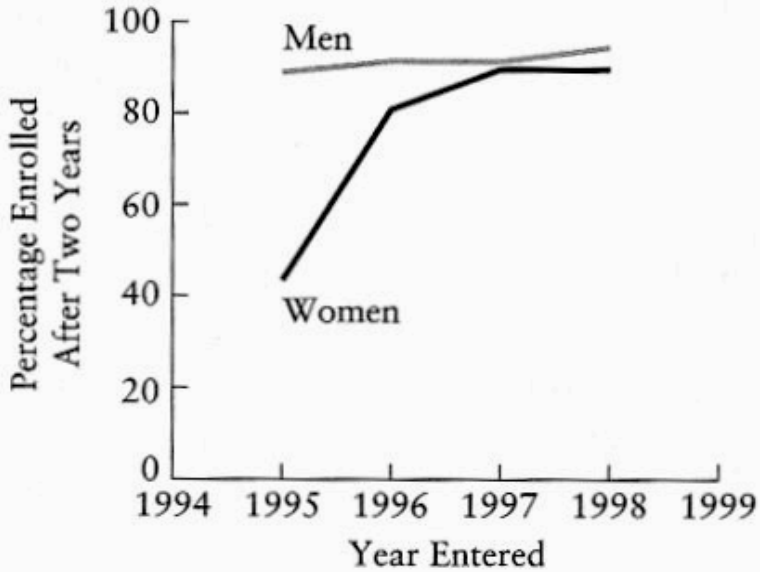


Figure 8.2
Persistence trends for students enrolled in the School of Computer Science

~ doubling for female students

Margolis & Fisher 2002

It is possible for academic institutions of higher education to have a significant impact on the numbers of women in science…

…while maintaining strong, competitive programs

Why another talk on women in science?

In the past 30 years:

Neutrino oscillations $\Rightarrow m_\nu$

CMB anisotropies $\Rightarrow$ flat universe

Women physics (full) professors $\Rightarrow$ 5%???

General recognition of problem of underrepresentation and willingness to address issue

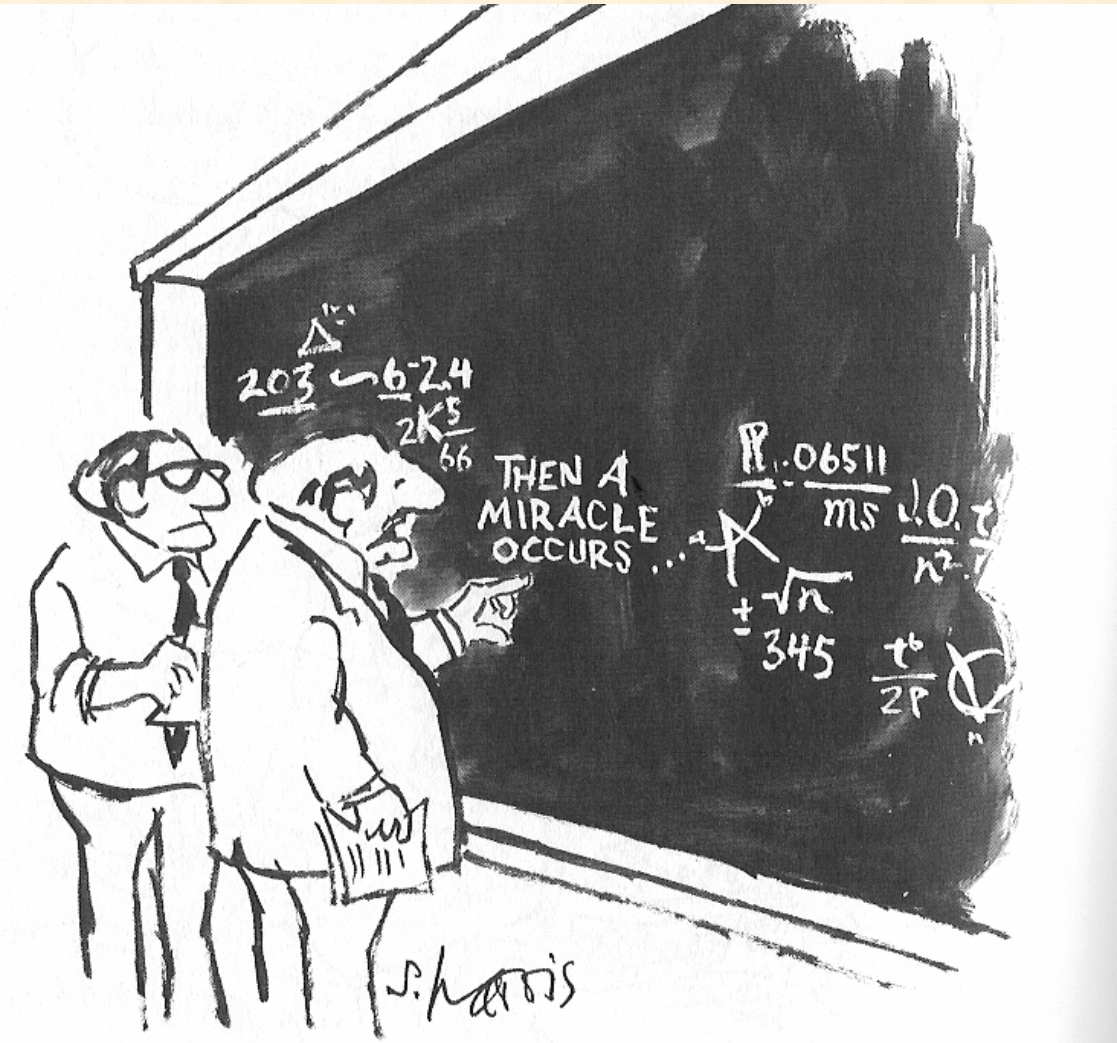
(although by no means universal)

+ General recognition of underrepresentation and willingness to address issue

- “Out of our hands” attitude
- Research on gender bias and successful programs not getting through to science community
- Low priority (in practice)
- Denial -> meritocracy is deeply cherished belief

☛ NOT USING CRITICAL THINKING SKILLS

No miracles in science:



"I think you should be more explicit here in step two."

We (the scientific community) need to start thinking like scientists

Approach this problem like any other:

1. What is the question?
2. Review what is already known about the data, detector, and backgrounds
3. Data analysis -- account for biases and backgrounds
4. Improve next generation experiment

Motivation

*Because we want to create and work within a system that identifies, encourages, and support the brightest and most motivated scientists and science students

- Fairness -- careers in science technology are rewarding (both financially and personally)

Occupations with the highest median earnings, May 2004

Occupation	Median earnings
Anesthesiologists	Greater than $145,600
Internists, general	Greater than $145,600
Obstetricians and gynecologists	Greater than $145,600
Oral and maxillofacial surgeons	Greater than $145,600
Orthodontists	Greater than $145,600
Prosthodontists	Greater than $145,600
Psychiatrists	Greater than $145,600
Surgeons	Greater than $145,600
Chief executives	$140,350
Family and general practitioners	137,090
Pediatricians, general	135,730
Airline pilots, copilots, and flight engineers	129,250
Dentists, general	123,060
Air traffic controllers	102,030
Engineering managers	97,630
Astronomers	97,320
Lawyers	94,930
Podiatrists	94,400
Judges, magistrate judges, and magistrates	93,070
Computer and information systems managers	92,570
Natural sciences managers	88,660
Petroleum engineers	88,500
Optometrists	88,410
Marketing managers	87,640
Physicists	87,450

US Dept. of Labor
Bureau of Labor Statistics

- Fairness -- careers in science technology are rewarding (both financially and personally)
- Trained workforce (National Academies Report 2006)
- Scientific literacy is essential in a democracy

⇒practices which improve the enrollment and retention of women are effective in creating environments in which all students can flourish

Whitten et al 2000

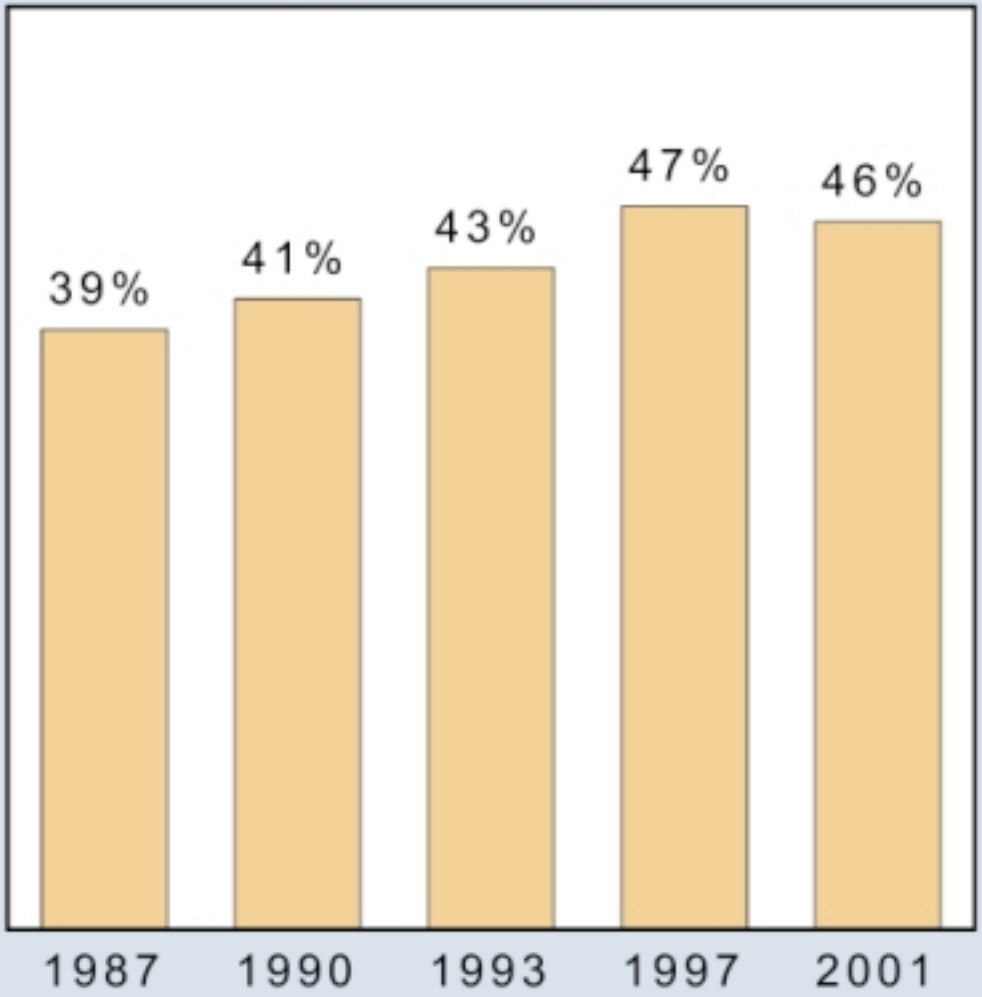
Blum et al 2006

Women in Physics

- Physics has the lowest percentage of women in math/science fields
- I’m a physicist

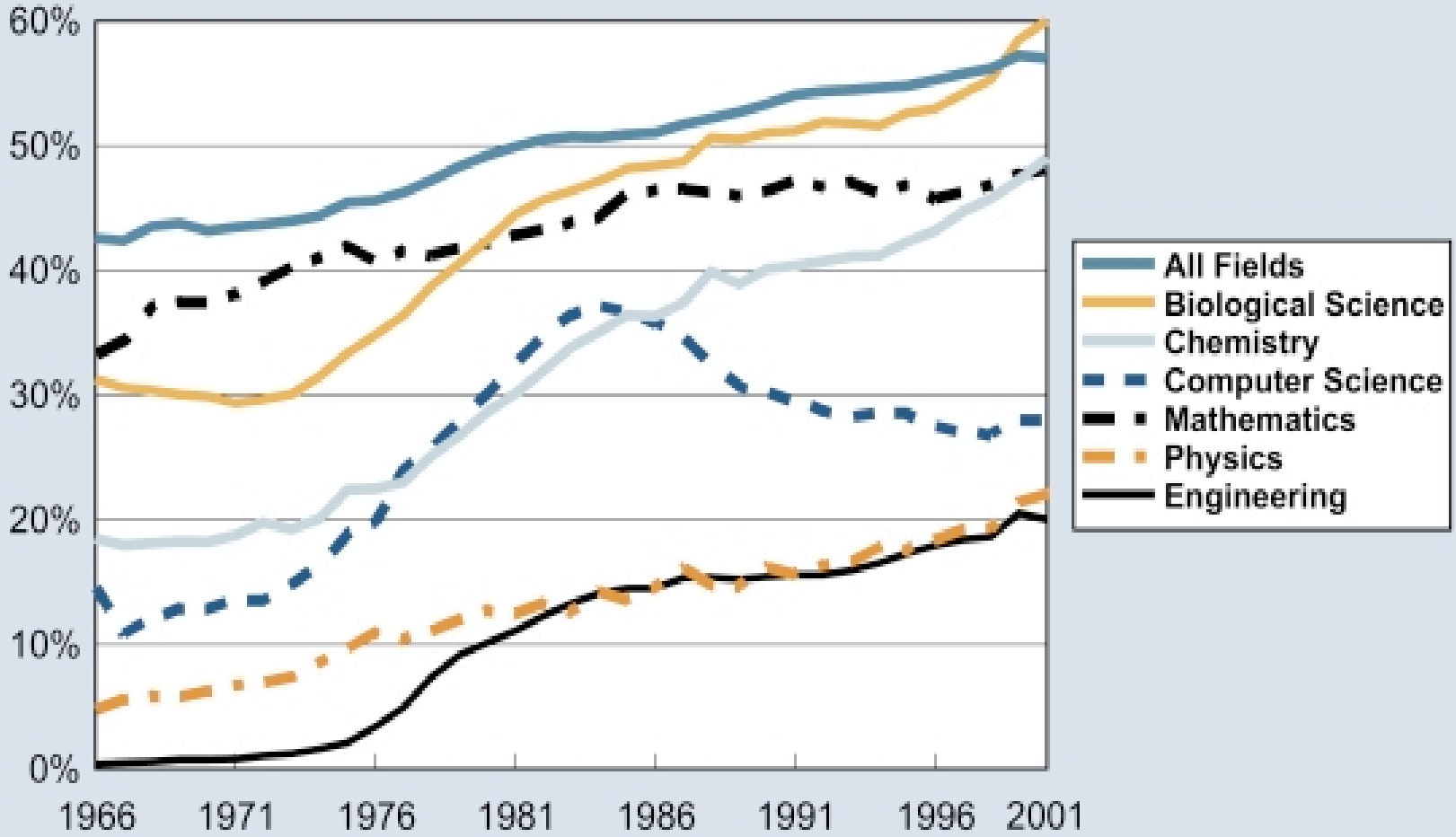
Data

Figure 2. Girls as a percentage of total enrollment in high school physics over time.



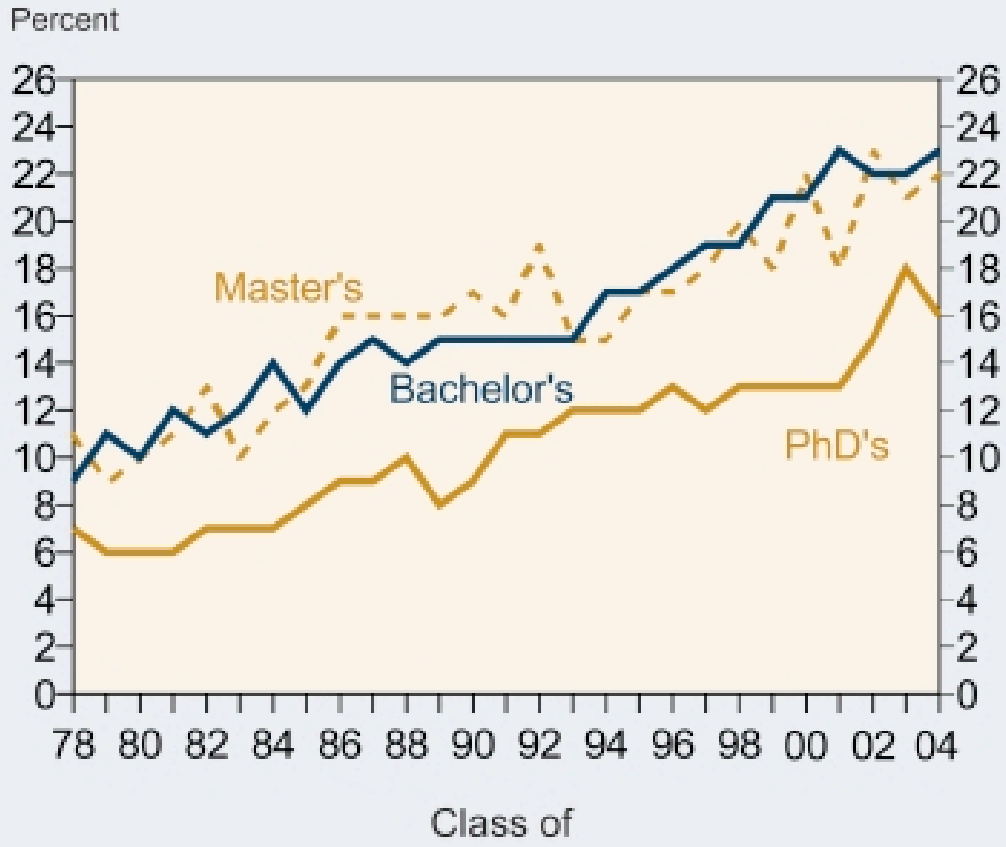
AIP Statistical Research Center: 1986-87, 1989-90, 1992-93, 1996-97 & 2000-01 High School Teacher Surveys.

Figure 8. Percent of bachelor's degrees earned by women in selected fields, 1966-2001.



National Center for Education Statistics. Data for academic year 1999 not available.
Compiled by AIP Statistical Research Center.

Figure 10. Percent of bachelor's degrees, masters degrees and doctorates in physics earned by women, 1978-2004.



Note: A form change occured in 1994 resulting in a more accurate representation of women among physics bachelors. Some of the increase in 1994 only, may be a result of that change.

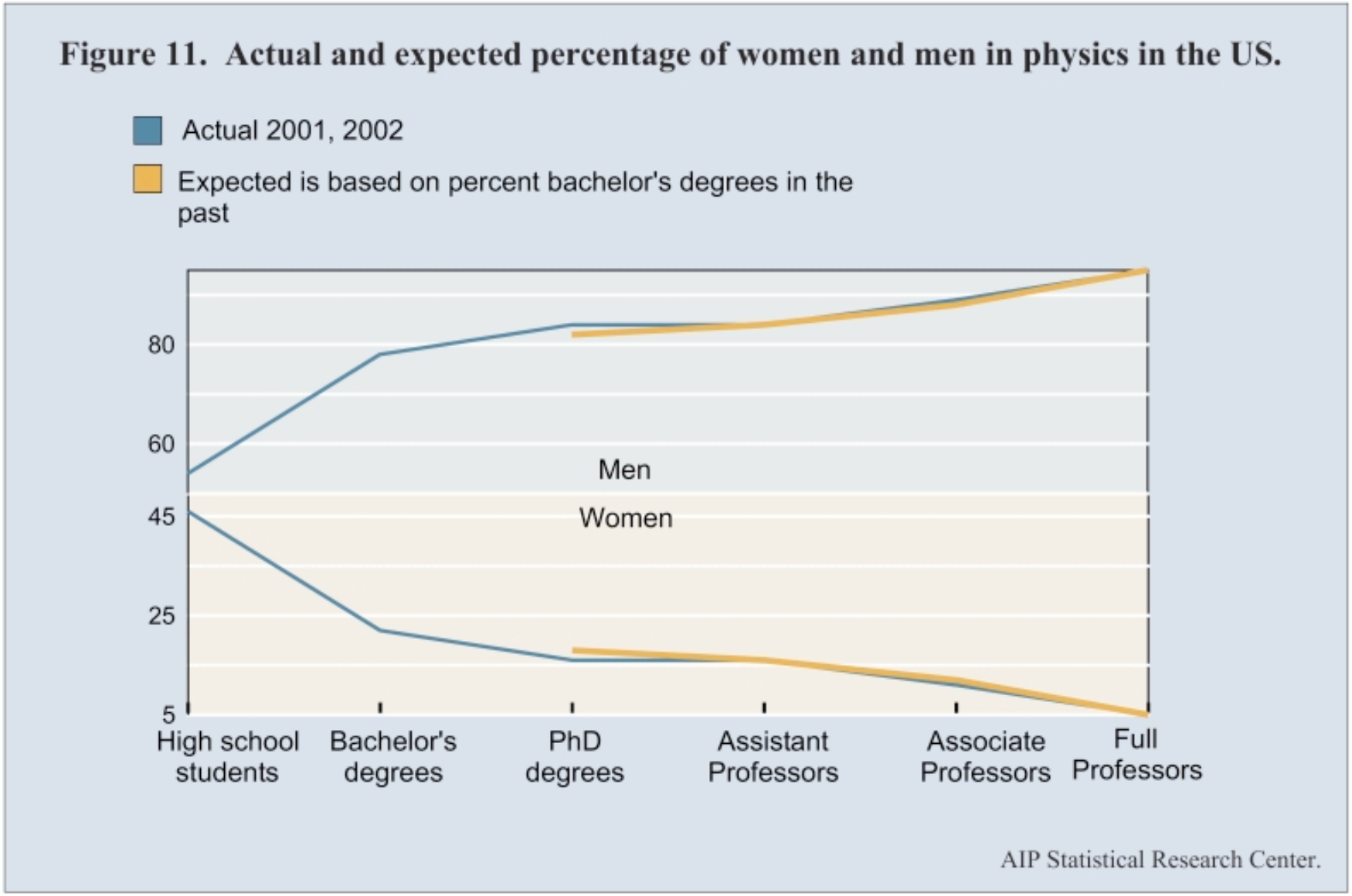
AIP Statistical Research Center, Enrollments and Degrees Report.

Table 6. Percent of faculty positions in physics held by women, 1994, 1998 and 2002.

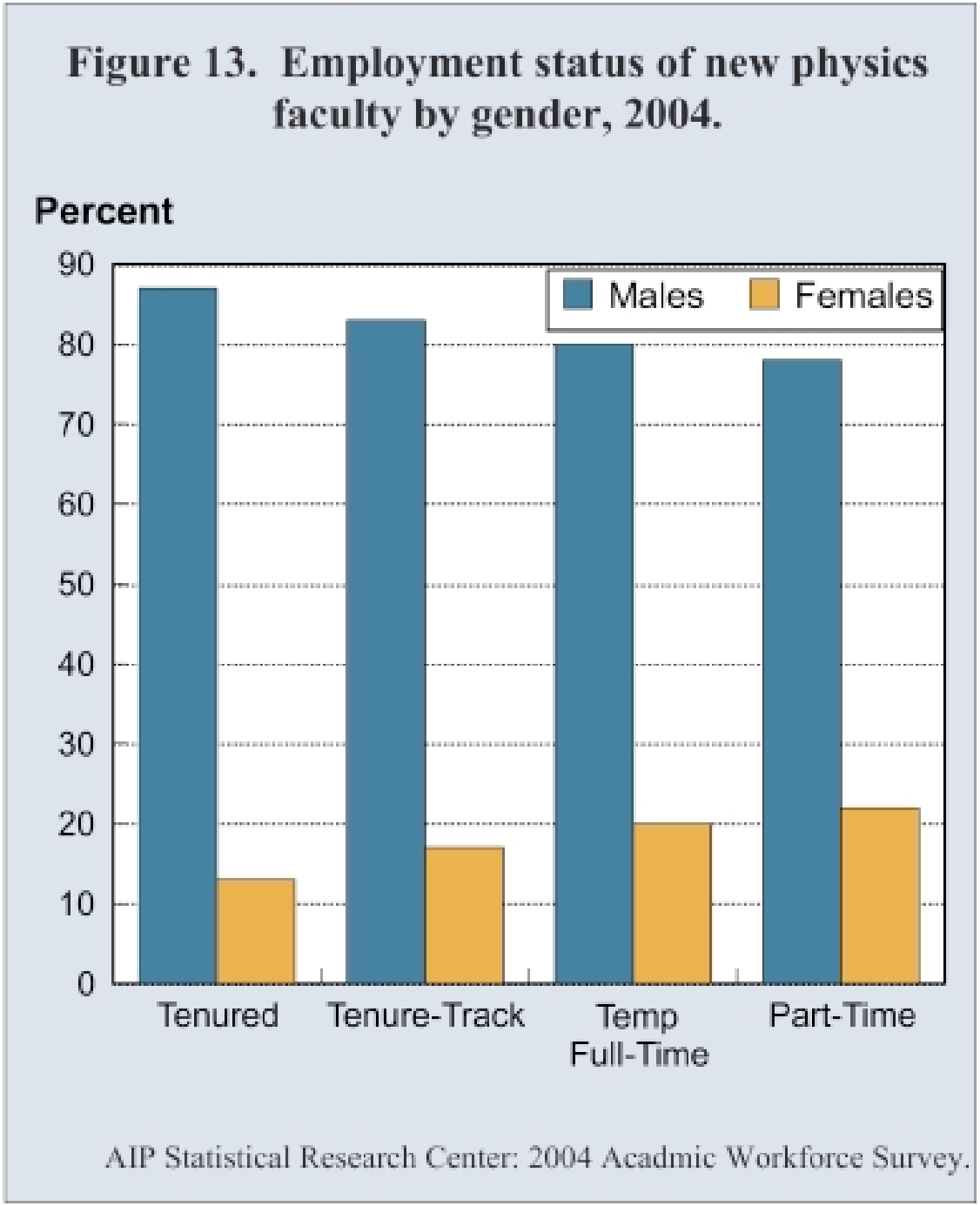
	1994 %	1998 %	2002 %
Academic Rank			
Full professor	3	3	5
Associate professor	8	10	11
Assistant professor	12	17	16
Instructor / Adjunct	N/A	N/A	16
Other ranks	8	13	15
Type of Department			
PhD	5	6	7
Master's	7	9	13
Bachelor's	7	11	14
Overall	6	8	10

AIP Statistical Research Center: 2002 Academic Workforce Survey.

Be careful interpreting this graph…



Ivie & Ray conclude that the main juncture at which the percent of women in physics drops dramatically is somewhere between high school and the attainment of a bachelors degree.



"…even when working in the same employment sector with the same years of experience, women in physics and related fields on average earn less than men."

Ivie & Ray 2005

“Although a majority of the responding women physicists said they would choose physics again, a majority also reported being discouraged about physics. Many spoke about negative interaction with colleagues, including many stories about discriminatory attitudes”

Table 17. Reasons Responding Women Physicists Gave for Being Discouraged About Physics

	Percent
Research	49
Funding	52
Interaction with colleagues	55
Climate for women	43
Personal life	48
Family obligations	35

*Respondents could choose more than one answer.

AIP Report 2006 “Women Physicists Speak Again” Ivie & Guo

Table 18. Percent of Responding Women Physicists Who Agreed That the Following Needs Improvement	
	Percent
Daycare cost	55
Daycare availability	65
Travel with young children	58
Balance of child care in family	69
Discrimination	65
Attitude about women in physics	80

AIP Report 2006 “Women Physicists Speak Again” Ivie & Guo

In Summary

- Full professors 5%
- All faculty 10%
- Climate remains troubling
- Main juncture at which physics loses women is between HS (46%) and attainment of bachelor’s degree (22%)

Why the drop between high school and bachelor's degree?

- Fewer (half as many) female high school seniors express intention to major in science (Xie & Shauman 2003)
- Those who do only 1/3 as likely to persist to degree

(Above data for combined STEM fields)

Pre-college cultural effects?

(Hypothesis that women are less interested in math/ science fields)

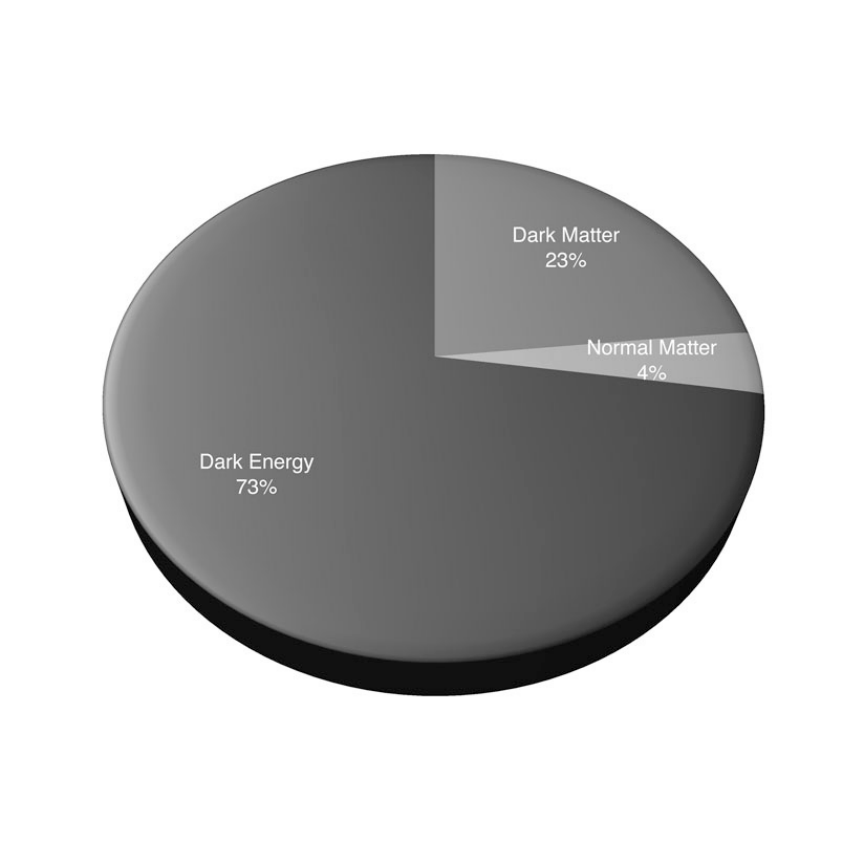
- But undergraduate degrees in chemistry and math almost 50% female
- And more than half of women who do earn science degree switch from non-science

Why is physics so far behind?

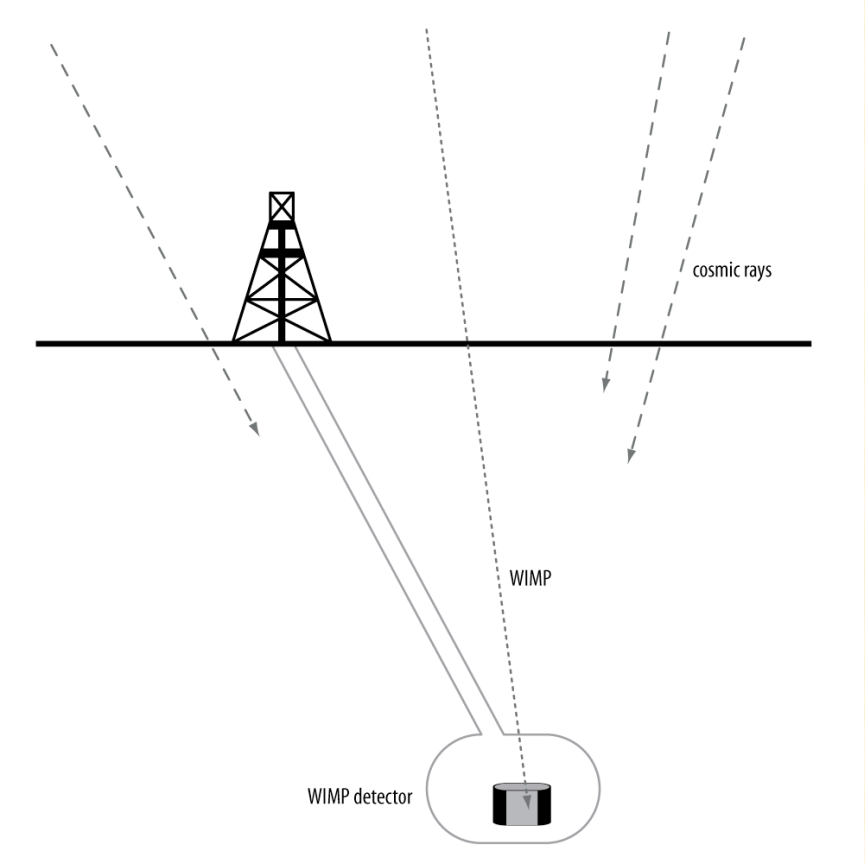
=> We don’t know

Detectors

Most of the Matter in the Universe is Dark

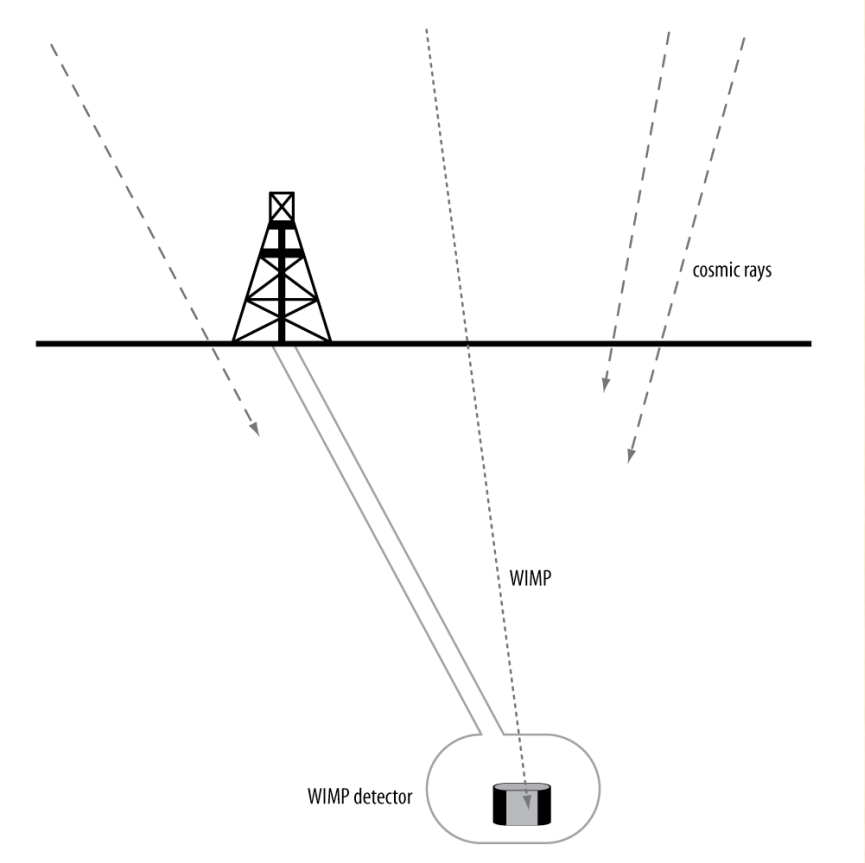


Dark Matter Detection



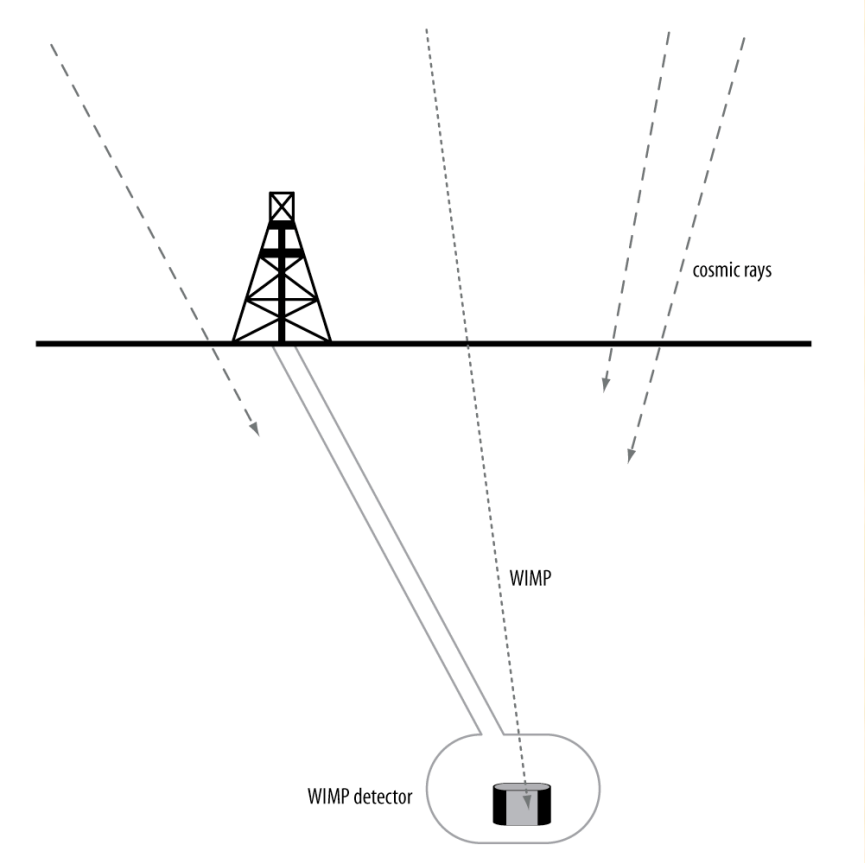
Build the best detector possible

Dark Matter Detection



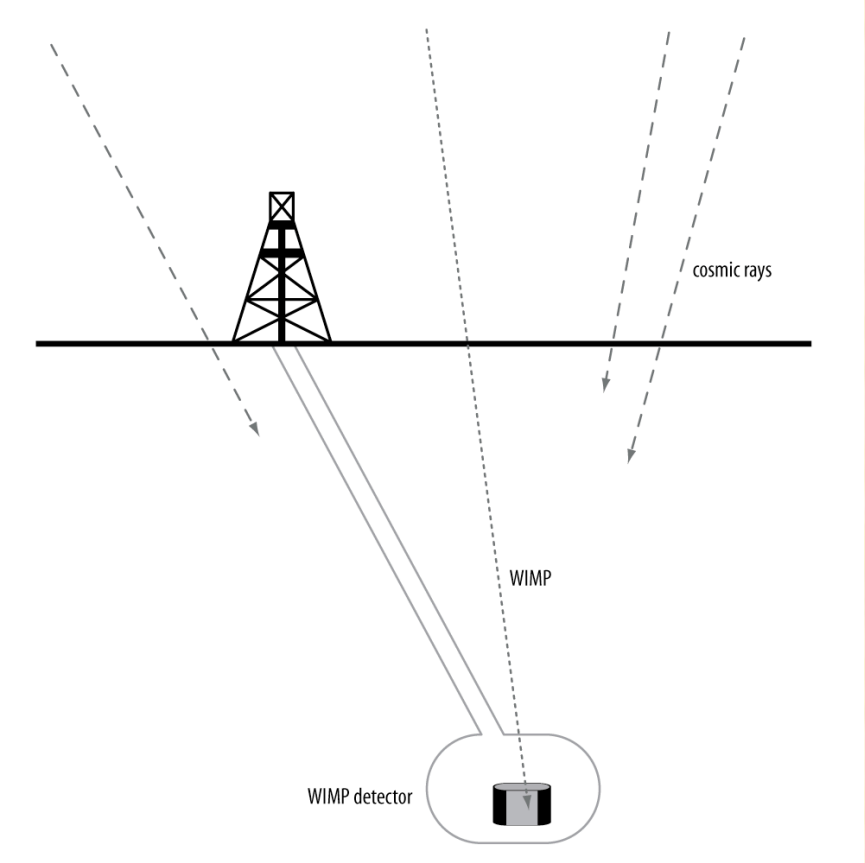
Test it: characterize response to various inputs

Dark Matter Detection



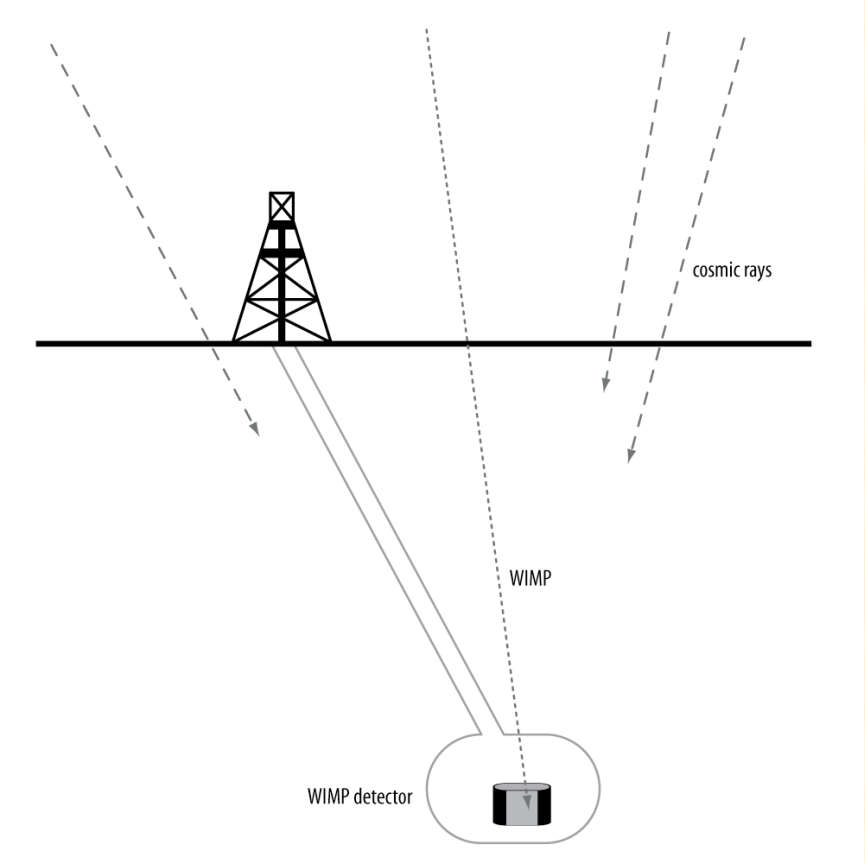
Understand backgrounds (literature; experts)

Dark Matter Detection



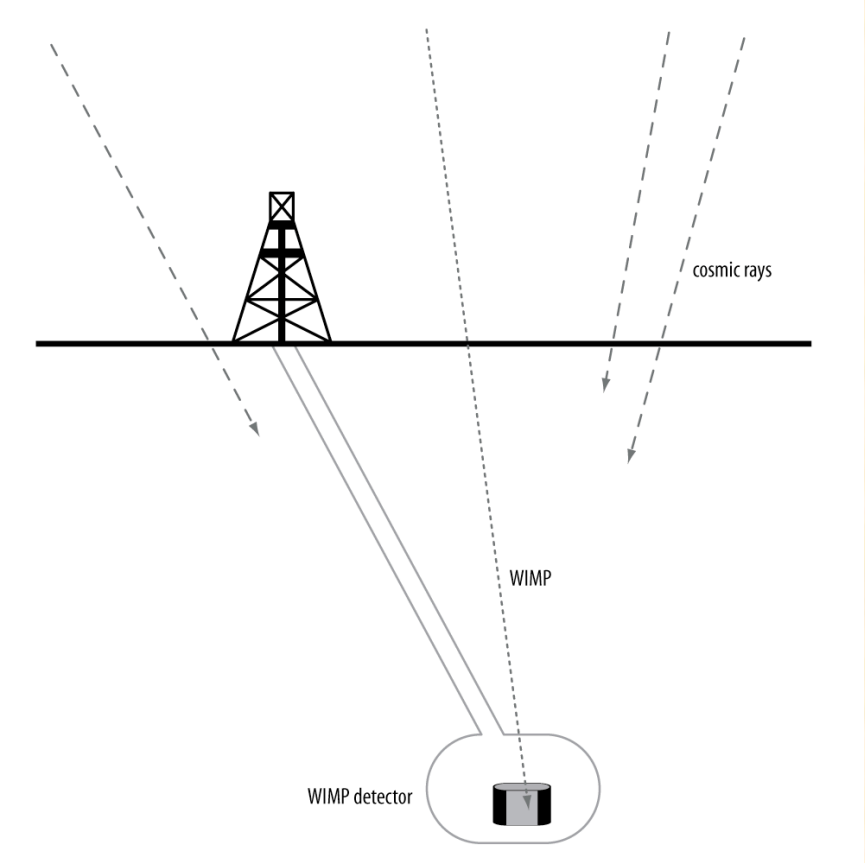
Place it deep underground

Dark Matter Detection



Measure background signal (radiation from rock walls, CRs,…)

Dark Matter Detection



Data analysis: eliminate/account for backgrounds and biases

Problem/Question:

$\Rightarrow$ Finding dark matter

Detector?

$\Rightarrow$ CDMS

Problem/Question:

$\Rightarrow$ Identifying and encouraging the next generation of physicists

Detector?

$\Rightarrow$ Current generation

Understand your detector

- We live in a highly gendered culture
- No one is exempt -- there are no perfect detectors
- Significant backgrounds exist

…Should sound familiar

Detector Response Characteristics

⇒ Both men and women respond to and evaluate male and female students/ candidates differently

Examples

There is a wealth of literature documenting
gender biases in human detectors and cultural “backgrounds”

Valian, V., *Why So Slow? The Advancement of Women*, Cambridge: The MIT Press (1998) and the many references within.

Wenneras, C. and Wold, A., Neopotism and Sexism in peer-review,” *Nature* 387, 341 (1997).

Rouse, C. and Goldin, C. "Orchestrating Impartiality: The Effect of 'Blind' Auditions on Female Musicians," *American Economic Review* (September 2000) .

Paludi, M.A. and Bauer W.D. *Sex Roles: A Journal of Research*, 9, 387 (1983).

Steinpreis, R.E., Anders, K.A. & Ritzke, D., “The impact of gender on the review of the curricula vitae of job applicants and tenure candidates: A national empirical study,” *Sex Roles*, 41, 509 (1999).

Orchestrating Impartiality

- Highly competitive
- Major orchestras ~ 3 hires/year
- Long history of discrimination

"Many of the most renowned conductors have, at one time or another, asserted that female musicians are not the equal

Rouse, C. and Goldin, C. "Orchestrating Impartiality: The Effect of 'Blind' Auditions on Female Musicians," *American Economic Review* (September 2000).

Blind auditions: the musician is hidden behind a screen

- Screen increases probability woman will advance to next level by 50%
- It increases by factor of 2-3 the probability that woman will be selected in final round

New hires:

1970's (pre-screen) 10% women
1990's 35% women

Switch to blind auditions can explain ~30% of this increase

Nepotism and sexism in peer-review

- Swedish Medical Research Council fellowships
- 3 data points: CV, publications, research proposal
- Reviewed/rated by 5 members of evaluation committee
- Ranked (0-4) in 3 parameters: scientific competence, relevance of proposed research, quality of proposed methodology
- Scores are multiplied; then averaged

Wenneras, C. and Wold, A., Neopotism and Sexism in peer-review," *Nature* 387, 341 (1997).

- Reviewers awarded lower scores to females on all 3 parameters, but largest difference in scientific competence
- Average multiplied score
  - female 13.8
  - male 17.0
- 4 women and 16 men awarded fellowships

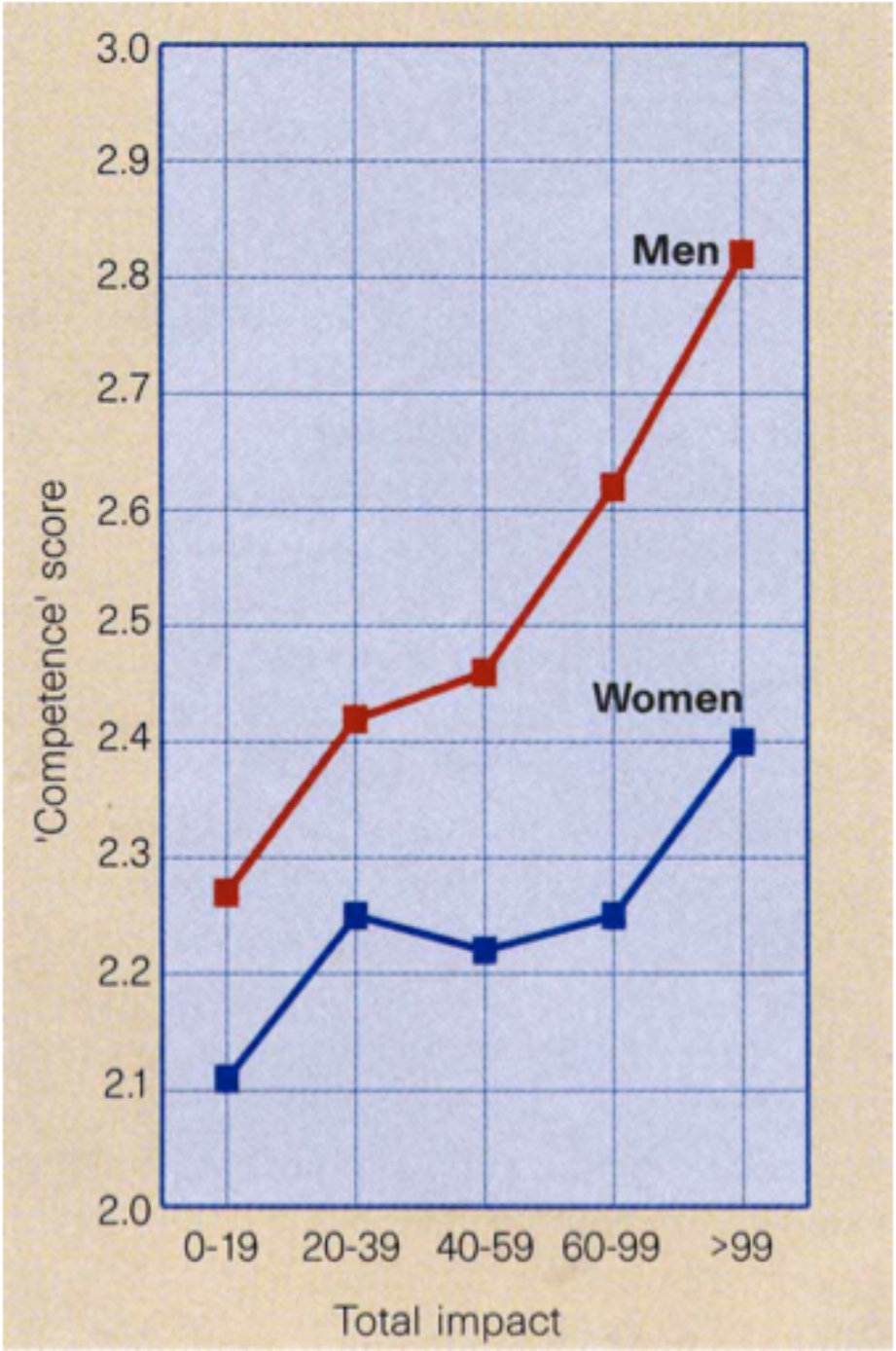
Reanalysis of productivity

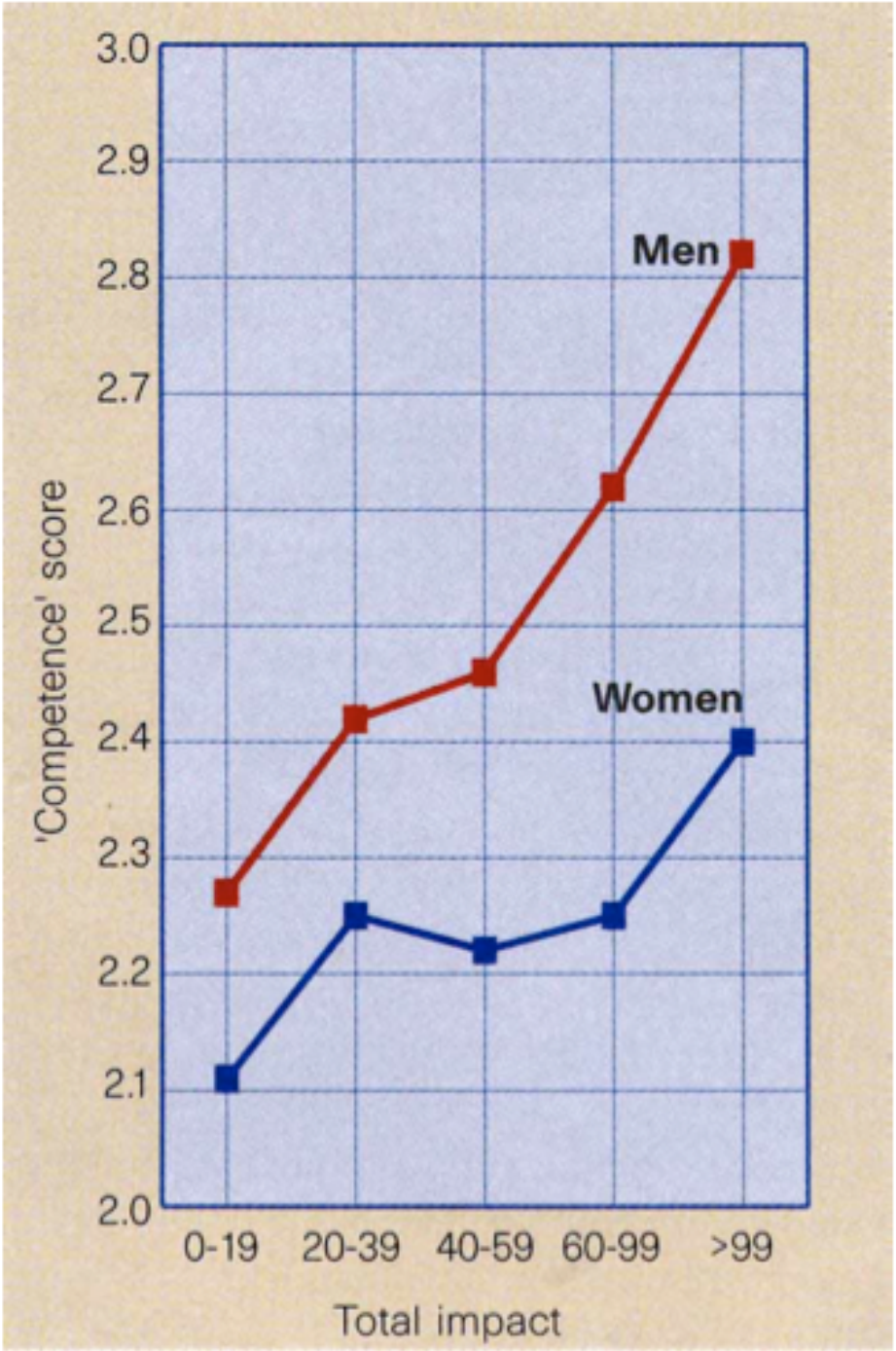
- # papers
- # first author papers
- Weighted by “journal impact factor”

(as defined by Journal Citation Reports;

times average paper in journal is cited in one year)

1 impact point = 1 paper published in journal with impact of 1


3.0
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
'Competence' score
Men
Women
0-19
20-39
40-59
60-99
>99
Total impact



Affiliation with committee member produced a similar advantage as male gender (equiv. of 67 impact points)

Gender advantage is equiv. of “3 extra papers in Nature or Science”

Need to identify and address misconceptions

Be aware of outside influences

Cultural effects also impact behavior

- Stereotype threat
- Self-confidence

- These can be triggered or exaggerated by minority status => critical mass is important

Stereotype threat

Trigger negative stereotype -> lower test scores (Steele & Aronson 1995)

- Students matched by SAT scores given section of GRE
- “test evaluates verbal ability” -> black students scored lower than white students
- “study of problem solving techniques unimportant to academic achievement” -> no difference in scores

- Shih, Pittinsky, Ambady 1999

- Activate identity (and corresponding stereotype) of Asian-American women

Asian

Female

Neutral

Shih, Pittinsky, Ambady 1999

- Activate identity (and corresponding stereotype) of Asian-American women

Score on math test

Asian	↑
Female	↓
Neutral	-

Self-confidence

- Confidence levels of talented young women plummet in 1st two years of college
- Similar decrease not seen in men
- Example: women with similar grades in CS report less confidence in ability (and this is highly variable over time)

(Brainard & Carlin 1998; Margolis & Fisher 2002; Seymour & Hewitt 1997; Astin & Astin 1993)

Leaving Science

- Students who declare intent to major in STEM field but switch out before graduation most often claim reason is "loss of interest"
- Margolis & Fisher 2002 -> complex relationship between confidence and stated interest in a field
- "Disidentification"

"…when you feel like you are not as good at a thing, you lose a little bit of interest"

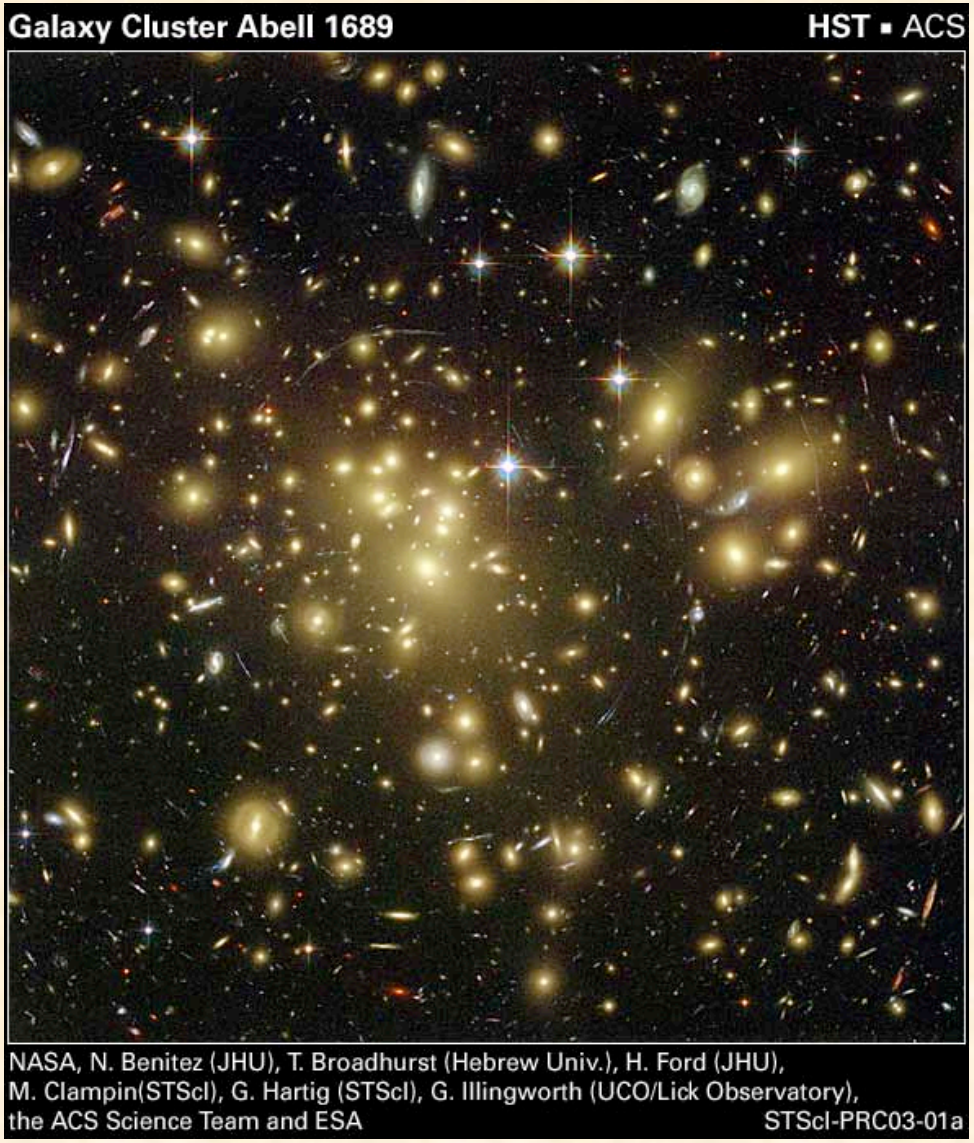
Interpretation of Data

Be aware of hidden variables:

- Self-confidence
- Assertiveness

Women and men perceived differently based on expectations/stereotypes

(Heilman et al 2004)

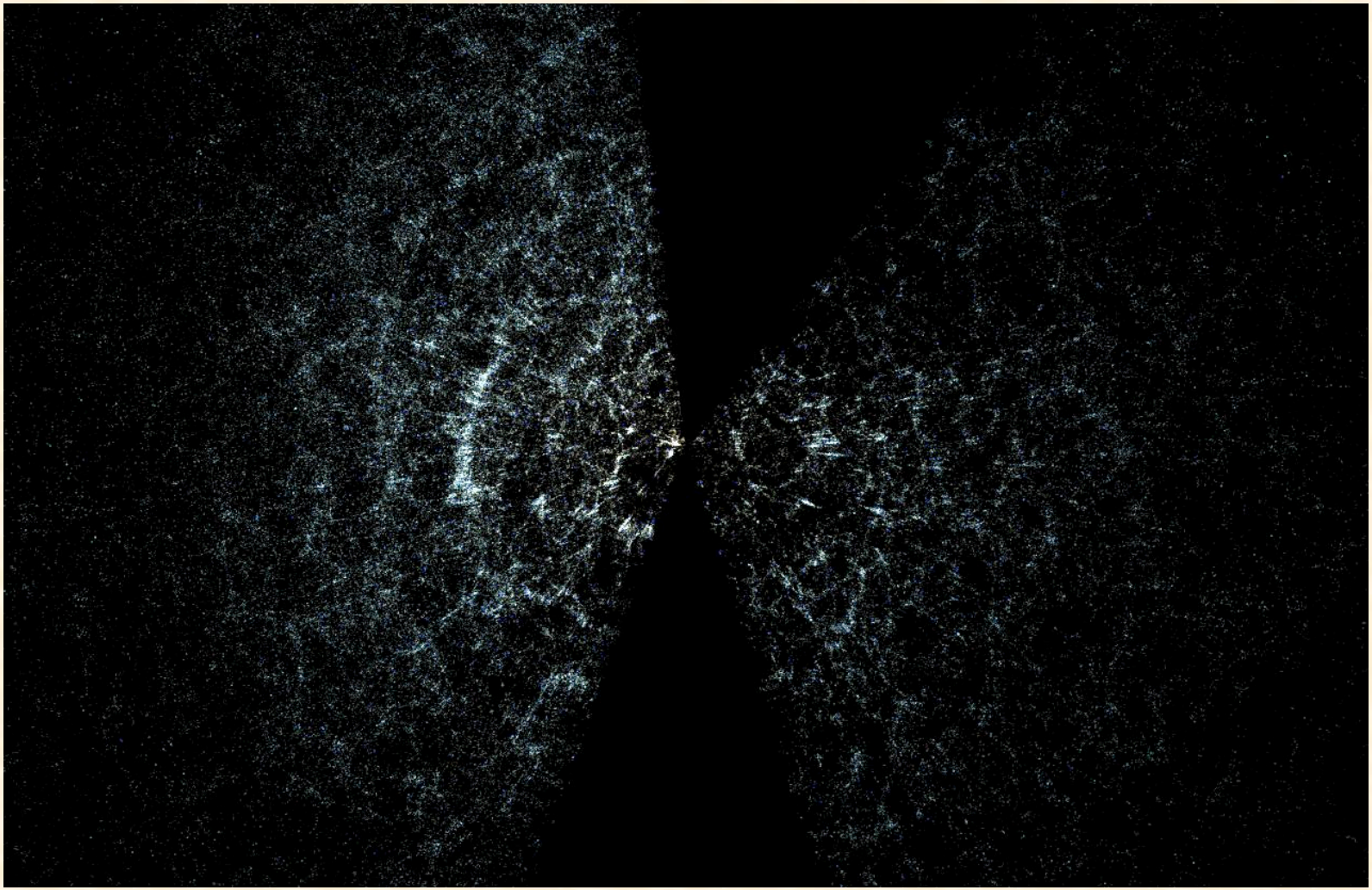


3D Mapping of galaxies
Distance -> redshift

Motions of galaxies w/in cluster introduce artifacts in redshift space

No intrinsic difference in galaxies

Fingers of God



What to do?

I don’t have a detailed, step-by-step plan guaranteed to increase the numbers

Neither do cosmologists know exactly how to find/characterize dark energy

=> Doesn’t stop them from getting started

Back to our first example:

CMU School of Computer Science

The first thing they did was conduct a study

(Margolis & Fisher 2002)

CMU Computer Science

- Recognized that prior (to college) programming experience was not a prerequisite for success in CS
- Minority status confers additional barriers (e.g. stereotype threat, limited access to informal support systems)
- Recognized need to reach out to HS AP instructors

Margolis & Fisher 2002; Blum, Frieze, Hazzan, Dias 2006

- New admissions policies
  - Dean urged focus on “applicants’ potential to play leadership roles in computing”
  - Admitted students “showed greater diversity … with no diminution in median grades and test scores”
- Curriculum changes
  - Broader definition of computer science (“not just programming”)
  - Offer first year students 4 entryways into CS curriculum depending on prior experience
  - Not made for purpose of becoming “female-friendly”

- Women@SCS -- undergraduate, graduate, faculty women

  Created to “formalize a program of professional, networking and mentoring opportunities for women” and explicitly “provide crucial educational and professional experiences generally taken for granted by the majority in the community”

- Culture shifted to more balanced in three domains:
  - Gender
  - Range of personalities and interests
  - Professional support afforded to all students

2004 studies found

- More similarities than differences in male/female attitudes toward CS, confidence in programming skills and feeling of “fitting in”
- Equal numbers of traditional “geeks” vs “broader interest” types (applications)

Start by thinking of this as a physics problem

=> Look at the data

- AIP
- NSF
- Your own institution/department

  - NSF proposal for longitudinal study to determine exit point for women in physics

Read the literature:

- Books -- Valian, Rosser, Eztkowitz et al
- Studies -- Margolis & Fisher, Xie & Shauman
- ADVANCE program websites usually have suggested references (including short handouts that summarize key points)

Take into account biases & backgrounds

- Pay attention to interactions (be aware of stereotype threat and confidence issues)
- Encourage all students in both formal and informal aspects of science
- Make sure all are well-trained and experienced in speaking up in class & seminars and giving talks

- Attempt to correct for biases (Hiring practices -- see Advance). Search for the second minimum in likelihood function
- Critical examination of structures/culture

  Are current practices really optimum?

  Margolis and Fisher 2002

- Find out what works at other institutions (or other departments)
- Motivate (chairs/deans) and/or lead (anyone) change
  - Publish stats
  - Stop hand holding

NAS Report 2006
Beyond Bias and Barriers:
Fulfilling the Potential of Women in Academic Science and Engineering

"it is not lack of talent, but unintentional biases and outmoded institutional structures that are hindering the access and advancement of women."

NAS Report 2006
Beyond Bias and Barriers:
Fulfilling the Potential of Women in Academic Science and Engineering

We can do better.