Numbers You Should Know
Part 1

A semi-quantitative profile of the profession

ASTR 8500 Spring 2022 Robert W. O'Connell

Sources?

- American Astronomical Society
- American Institute of Physics
- NSF, NASA, other agencies
- UVa documents
- Literature and general media sources
- ROMEs = rough order magnitude estimates

PRESENTATIONS AND RESOURCES

A. *Course Assignments*

B. *Numbers You Should Know* (O'Connell)

NSF Outlook (AAS Town Hall, Jan 2020)
NASA Outlook (AAS Town Hall, Jan 2020)

NSF Outlook (AAS Town Hall, Jan 2022)
NASA Outlook (AAS Town Hall, Jan 2022)

"Facts of Life for New Teachers in the Astronomy Nonmajors Curriculum" (O'Connell, AstEdRev, 6, 1, 2007)
"Production Rate and Employment of PhD Astronomers" (Metcalf, PASP, 120, 229, 2008)
"A Closer Look at Astronomy Faculty" (Ivie, AIP, 2009)
BA Degree Gender Gap By Field, 1970-2010 (Olson graphic, 2013)
"Astronomy Enrollments and Degrees" (Mulvey & Nicolson, AIP, 2014)
"Longitudinal Study of Astronomy Graduate Students" (Ivie, AIP, 2014)
"Doctorate Recipients from US Universities" (NSF, 2015)
"Astronomy Degree Recipients Initial Employment" (Pold, AIP, 2015)
"Women's and Men's Career Choices in Astronomy and Astrophysics" (Ivie et al., PRPER, 12, 020109, 2016)
"A Survey of U.S. Astronomers" (Spuck, PhD Thesis, WVU, 2017)
"Degree Plus One, Employment & Salaries" (Mulvey & Pold, AIP, 2019)
"Long Term Trends in the Astronomical Workforce" (Momcheva, Astro 2020 White Paper)
"Gender & the Career Outcomes of PhD Astronomers in the US" (Perley, PASP, 131:114502, 2019)

C. *Navigating the Early Career Job Market* (Meyer and McGuire)

AAS Job Register
Astronomy Rumor Mill (astrobetter)

"The Professor Is In: The Essential Guide to Turning Your Ph.D. Into a Job" (Kelsky)

D. *Consolidated Faculty Advice for Graduate Students*

"Tips for Success in Observational Astronomy" (O'Connell)

A National Perspective on Astronomy

We're #3 among STEMM fields in media impact:

#1 Health & Medicine
#2 Environment
#3 Astronomy & Space

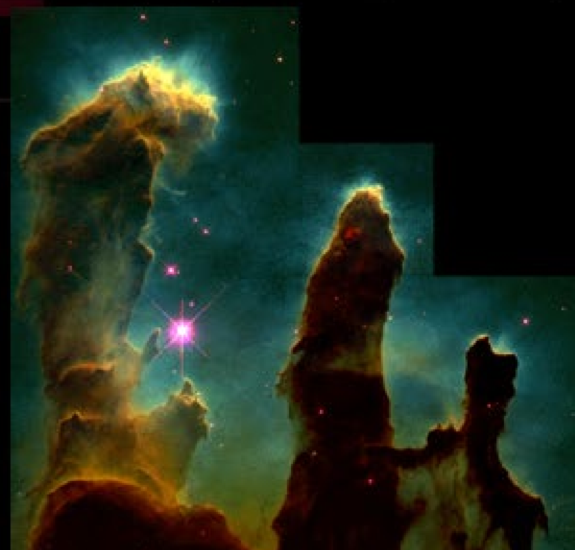
We're #1 in impact per practitioner!

Total STEMM employment: 16 million

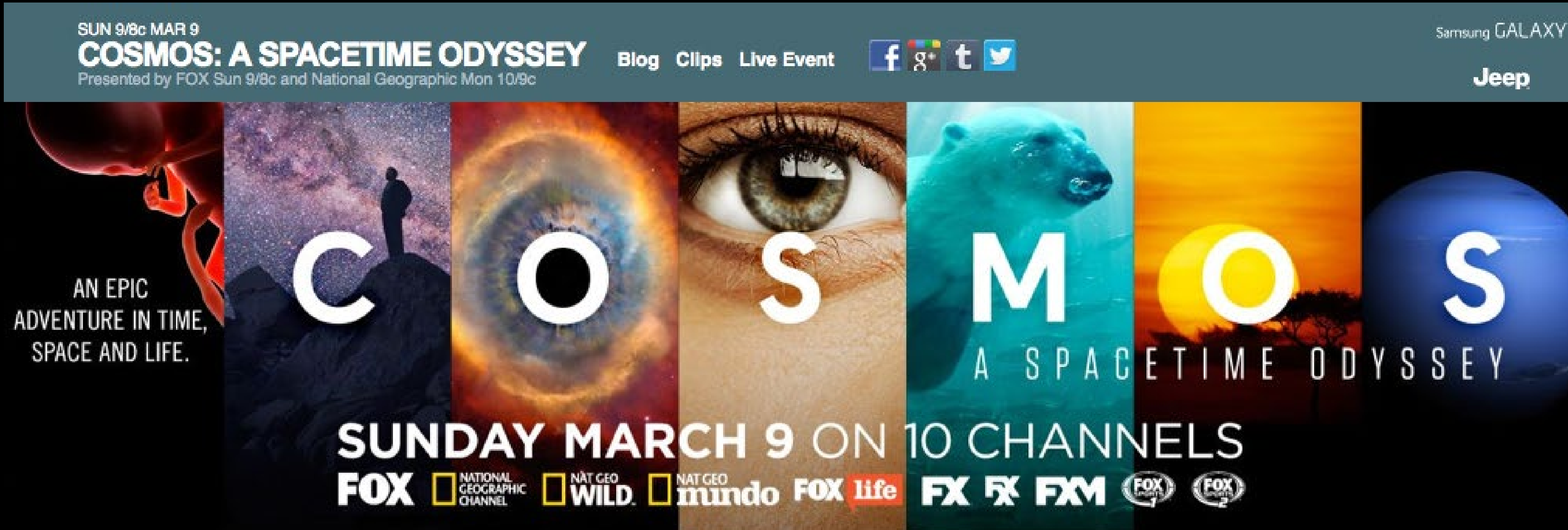
Total astronomy & space science employment: ~20-30 thousand



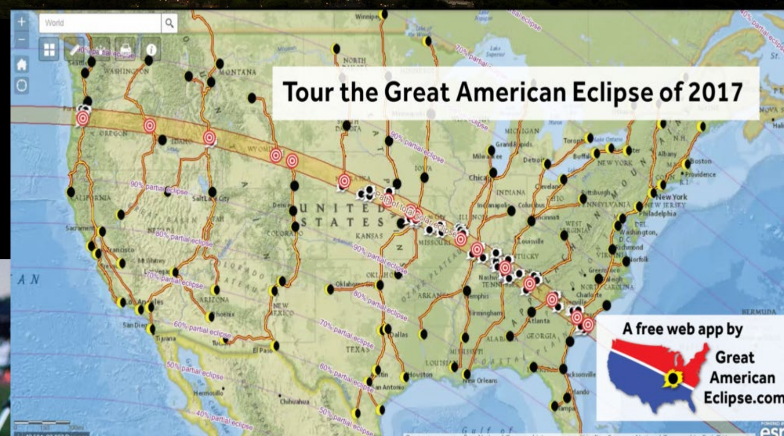







SUN 9/8c MAR 9
COSMOS: A SPACETIME ODYSSEY
Presented by FOX Sun 9/8c and National Geographic Mon 10/9c
Blog
Clips
Live Event
Samsung GALAXY
Jeep
AN EPIC ADVENTURE IN TIME, SPACE AND LIFE.
COSMOS
A SPACETIME ODYSSEY
SUNDAY MARCH 9 ON 10 CHANNELS
FOX
NATIONAL GEOGRAPHIC CHANNEL
NAT GEO WILD
NAT GEO mundo
FOX life
FX
FXM

Eclipse USA 2017



The New York Times

215 Million Americans Watched the Solar Eclipse, Study Finds

Todd Heisler/The New York Times

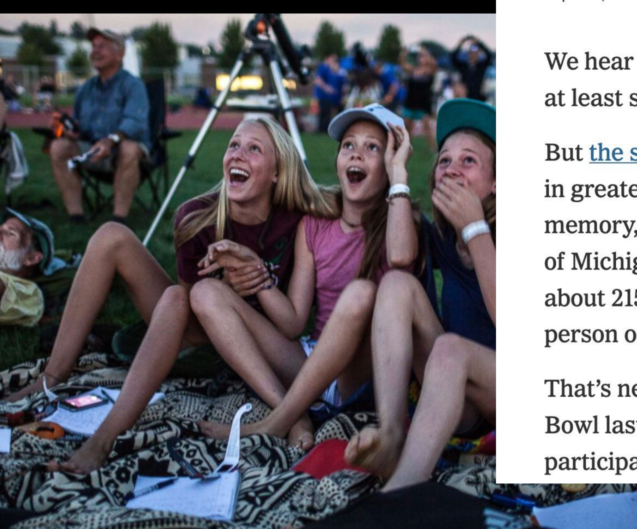
By Jonah Engel Bromwich

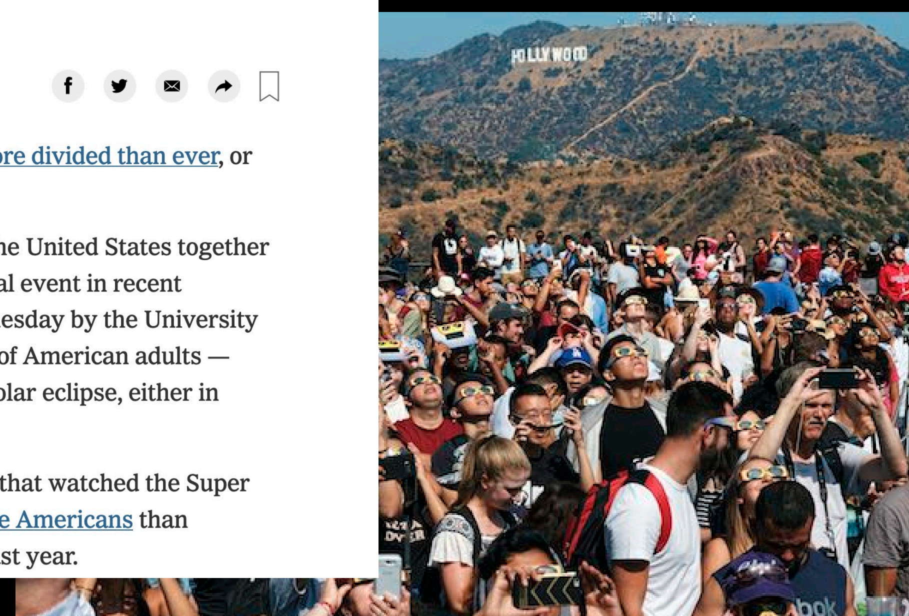
Sept. 27, 2017

We hear it all the time: Americans are more divided than ever, or at least since the Civil War.

But the solar eclipse on Aug. 21 brought the United States together in greater numbers than most any national event in recent memory, according to a study released Tuesday by the University of Michigan. It estimated that 88 percent of American adults — about 215 million people — watched the solar eclipse, either in person or electronically.

That's nearly twice the number of people that watched the Super Bowl last year. It's almost 30 percent more Americans than participated in the presidential election last year.



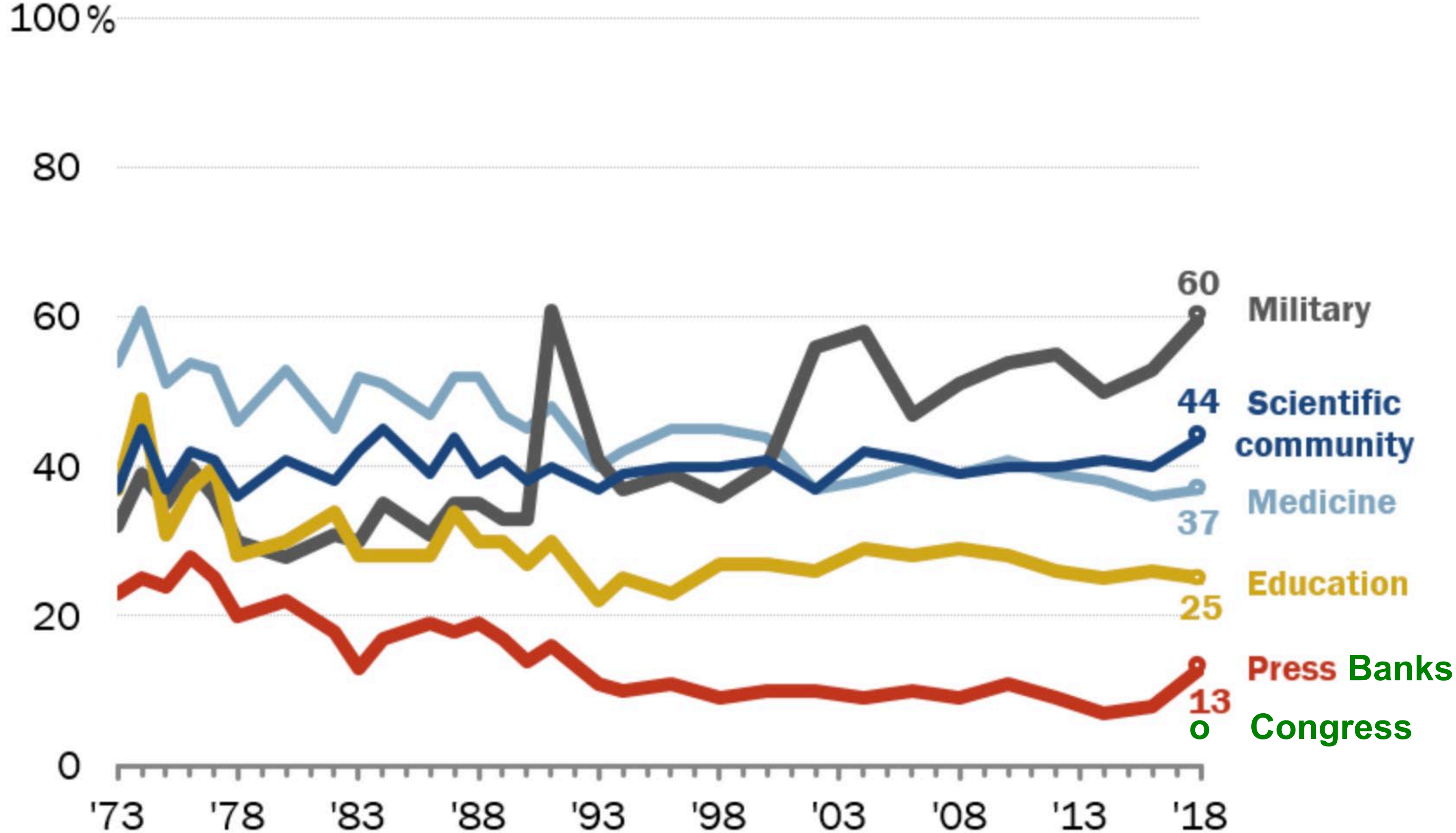


"Scientist" is the #4 most prestigious profession

(Harris Poll, 2014)

Confidence in leaders of the military has gone up; confidence in some other institutions is declining

% of U.S. adults who say they have a great deal of confidence in the people running each of these institutions



Note: Respondents who gave other responses or who did not give an answer are not shown.
Source: General Social Surveys, NORC.

PEW RESEARCH CENTER (2018 data)

250,000

= Number of college students enrolled annually in elementary astronomy courses

$425,000

= National budget for astronomy
per astronomer

THE NATIONAL BUDGET FOR ASTRONOMY (2016)

NSF	NASA	DOE, DOD	Univ/Priv*	Total**	Number Astronomers***	$$/Astronomer
$250M	$2950M	~$50M	~$150M	$3400M	~8000	$425,000

*Research support; excludes basic faculty salaries.

**The federal budget for astronomy is ~0.08% of the total federal budget of $4.0T or $10.09 per US citizen per year.

***AAS membership, 2016

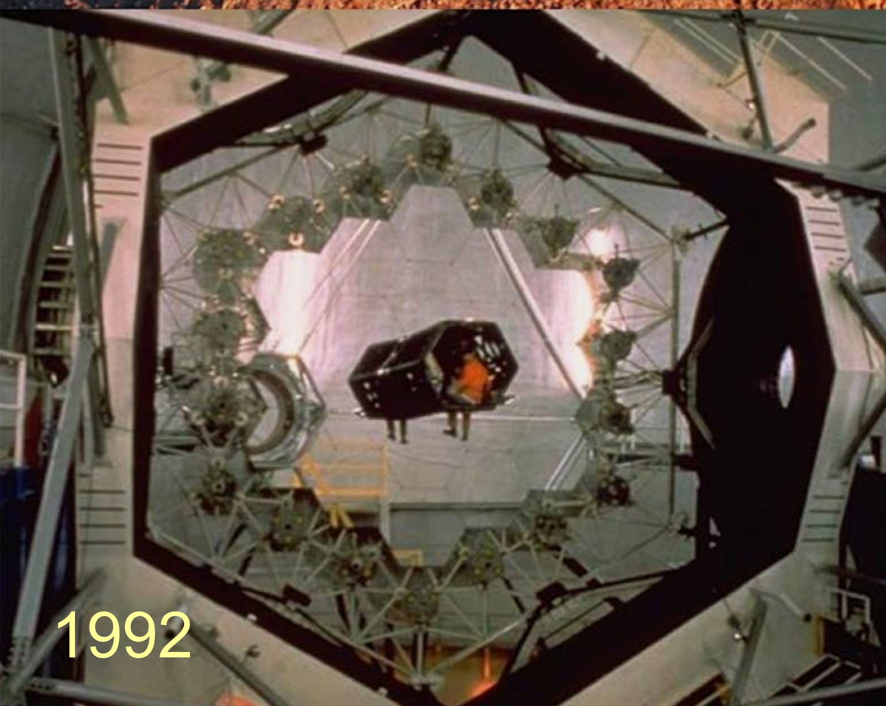

DEPTH
GAUGE
90 ft

$425,000

= National budget for astronomy <u>per astronomer</u>

...BUT: mostly in the form of <u>*shared observing facilities*</u>


1974

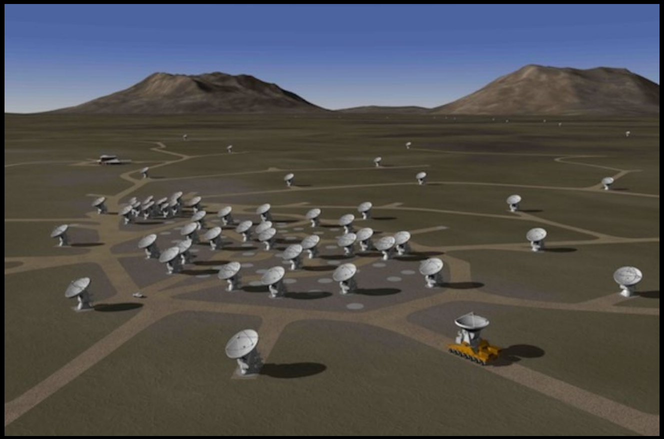
1990

1992

2011

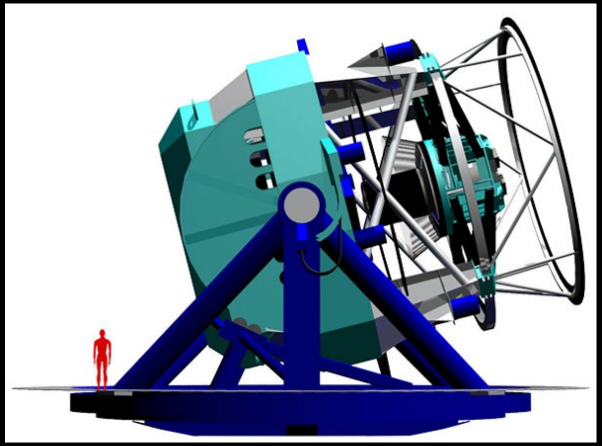
Astronomy is ~uniquely dependent on large, shared experimental facilities

Astronomical facilities have <u>long</u> productive lifetimes; a blessing & a curse

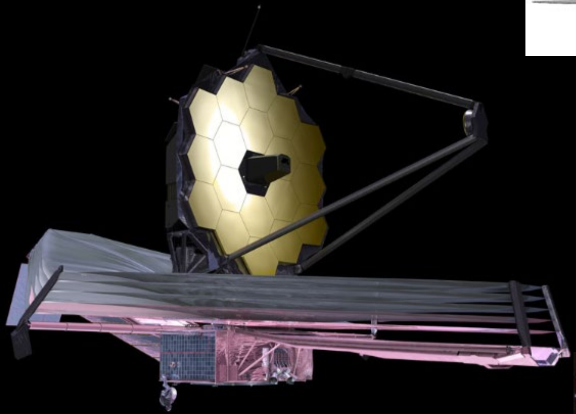
Promise of the Next Decade



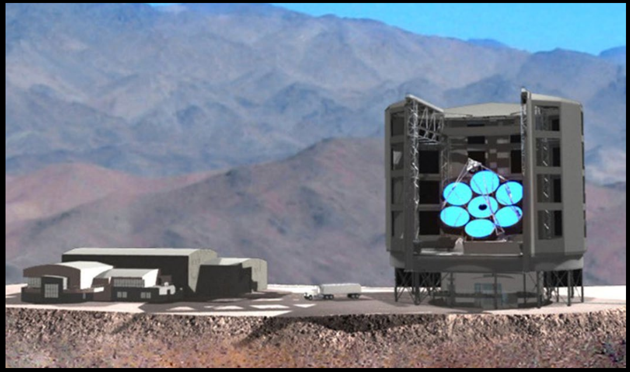
ALMA



Rubin/LSST



JWST



GMT

Roman/WFIRST

The Job Market

WHEW!

JAMES WEBB SPACE TELESCOPE

344 possible single point failures

....all avoided

$60M/year for GO programs

Kinds of Jobs for Astronomers

- **Postdoctoral**
  - Short-term (1-3 yr) research positions (mostly directed)
- **Research Scientists**
  - Mostly semi-permanent. Large range, from support to independent researchers. Universities, observatories, government labs (e.g. NRAO, NOIRLab, GSFC, STScI, USNO). Independent contractors (e.g. JHU/APL, SWRI)
- **University Faculty**
  - Short term contractual and permanent (tenured) Research and teaching
- **Non-astro-research Government**
  - E.g. NASA, NSF, DOD, DOE, NOAA, etc.
- **Non-astro-research Private Sector**
  - "Beltway Bandits," high-end computing, aerospace, sensors & optics, medical imaging, communications...

Kinds of $$$

- **"Hard" money (reliable, long-term)**
  - Tenured faculty
  - Civil servants
  - Tenured & senior staff at national labs
- **"Soft" money (term-limited, grants, contracts)**
  - Postdocs
  - "Adjunct" faculty
  - Many "research scientists"
  - Federal contractors (e.g. SWRI)
  - Other private sector

2%

= Unemployment rate for astronomers

~ Transition rate

➔ ~ Full employment

Astronomy Long-term PhD Employment Pattern Through the 1990's:

~1/3 Faculty

~1/3 Research Scientists

~1/3 Non Astronomy

(Faculty + Research Scientists: 65%)

(Perley 2019)

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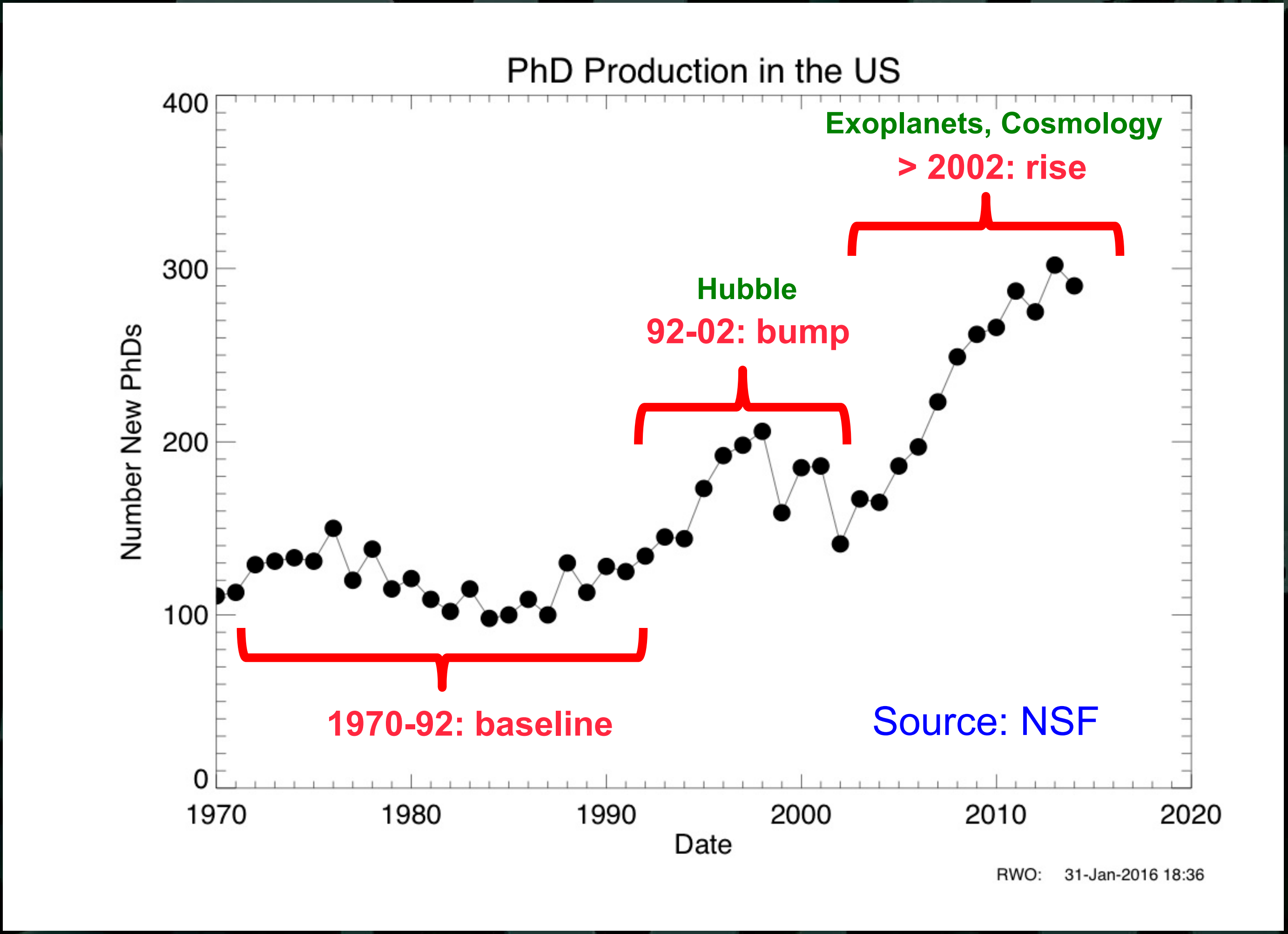
How many jobs?

~8500

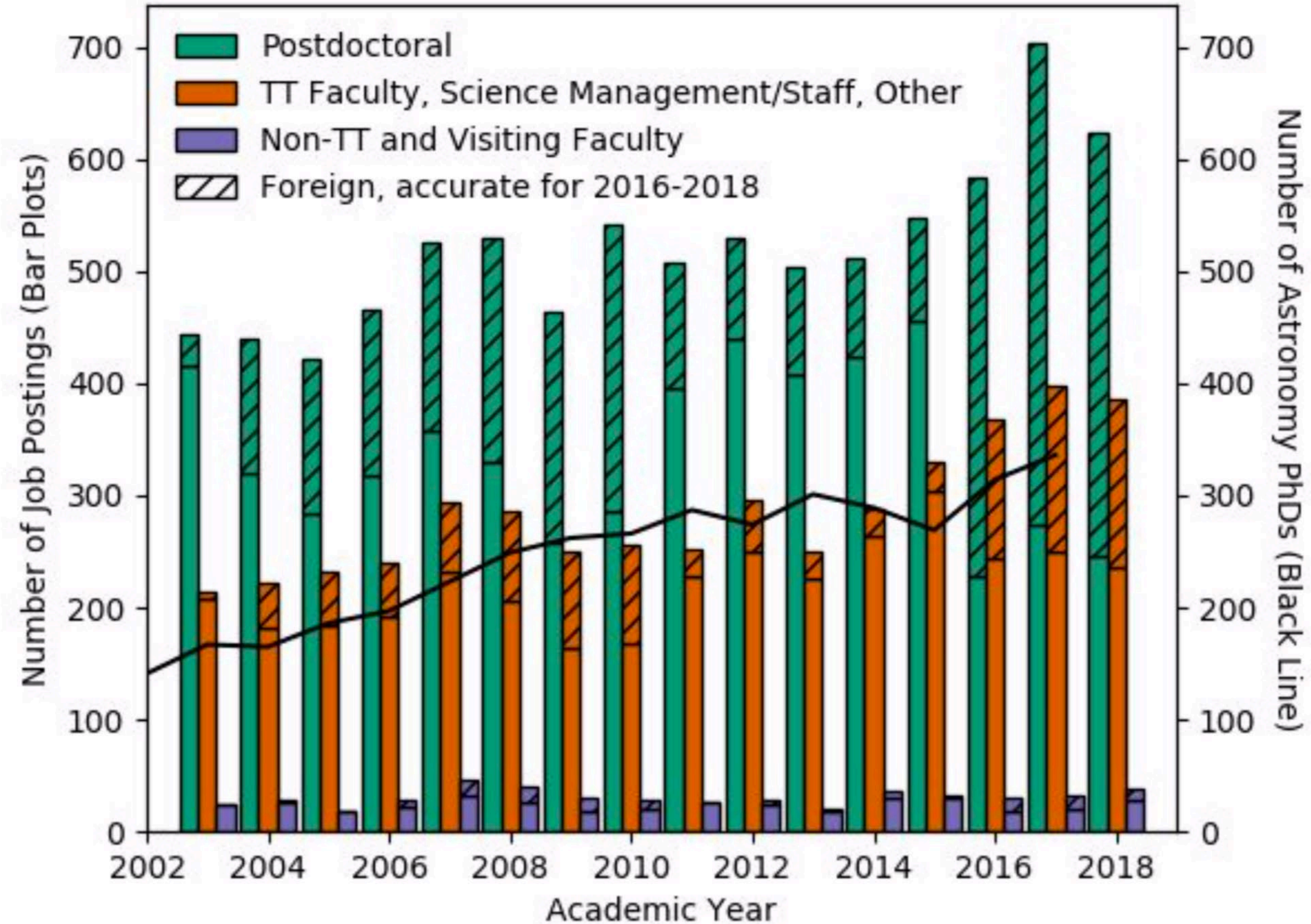
= Membership of AAS + Nonmembers

- Non-grad degrees

Production of New Astronomy PhD's



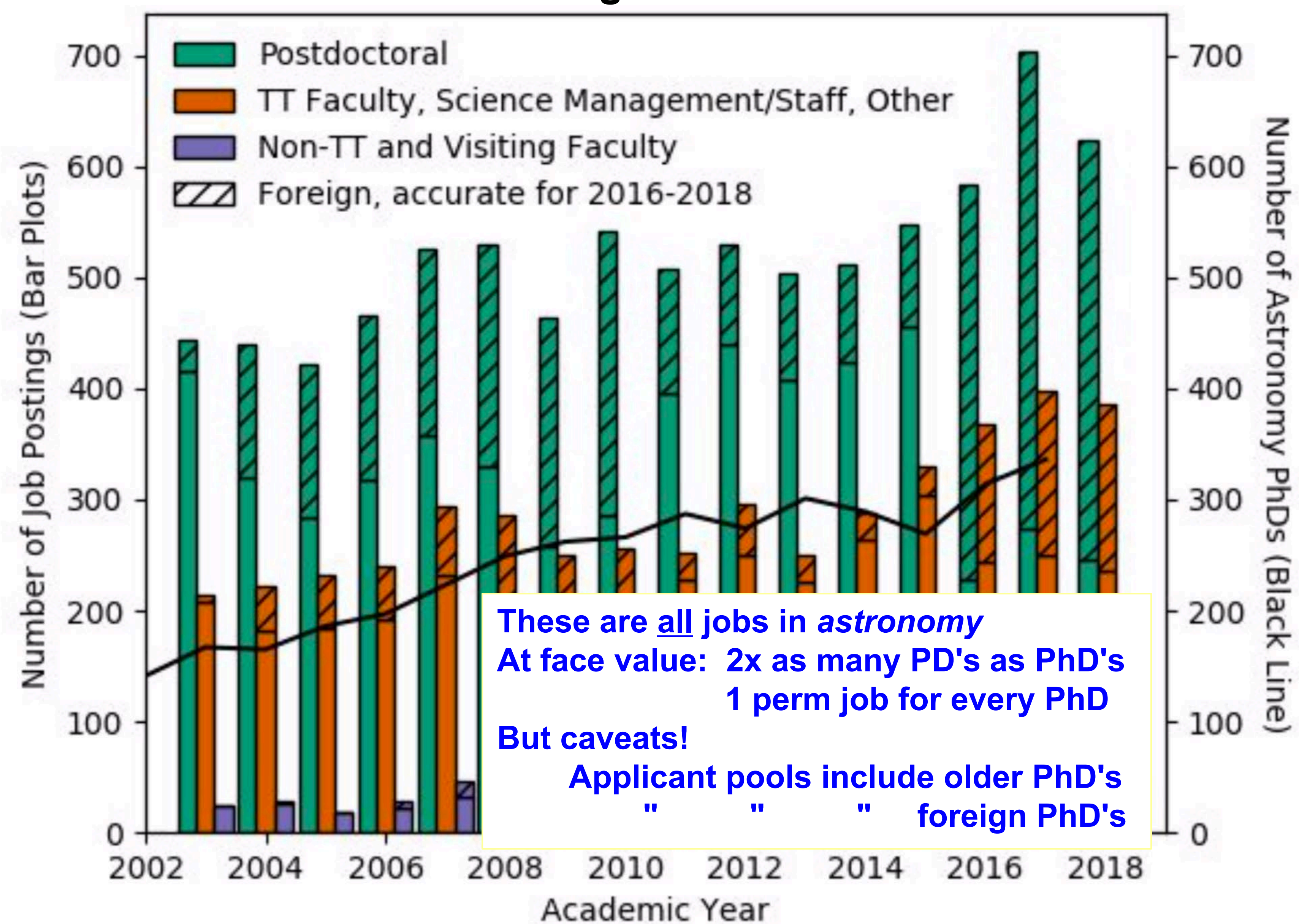
AAS Job Register Statistics



Black line: PhD's produced

(Kamenetzky, White Paper, 2019)

AAS Job Register Statistics



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Employment Demographics Studies

Perley 2019

Publications of the Astronomical Society of the Pacific, 131:114502 (7pp), 2019 November
https://doi.org/10.1088/1538-3873/ab0ce4

CrossMark

Gender and the Career Outcomes of Ph.D. Astronomers in the United States

Daniel A. Perley
Astrophysics Research Institute, Liverpool John Moores University, IC2, Liverpool Science Park, 146 Brownlow Hill, Liverpool L3 5RF, UK; d.a.perley@ljmu.ac.uk
Received 2019 February 10; accepted 2019 February 25; published 2019 September 24

Abstract

We analyze the postdoctoral career tracks of a nearly complete sample of astronomers from 28 United States graduate astronomy and astrophysics programs spanning 13 graduating years ($N = 1063$). A majority of both men and women (65% and 66%, respectively) find long-term employment in astronomy or closely related academic disciplines. We find no significant difference in the rates at which men and women are hired into these jobs following their Ph.D.s or in the rates at which they leave the field. Applying a two-outcome survival analysis model to the entire data set, we measure a relative academic hiring probability ratio for women versus men at a common year-post-Ph.D. of $H_{F/M} = 1.08^{+0.20}_{-0.17}$ and a leaving probability ratio of $L_{F/M} = 1.03^{+0.31}_{-0.24}$ (95% CI). These are both consistent with equal outcomes for both genders ($H_{F/M} = L_{F/M} = 1$) and rule out more than minor gender differences in hiring or in the decision to abandon an academic career. They suggest that despite discrimination and adversity, women scientists are successful at managing the transition between Ph.D., postdoctoral, and faculty/staff positions.

Key words: sociology of astronomy

Online material: color figures, machine-readable table

Employment Demographics Studies

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Followed actual post-PhD histories of over 1100 individual astronomers, unlike earlier studies using broad statistical measures or unreliable reporting (e.g. the "Rumor Mill" site).

Data for 2000-2012.

Perley 2019

12-Year Post-PhD Statistics (Data 2000-2012)

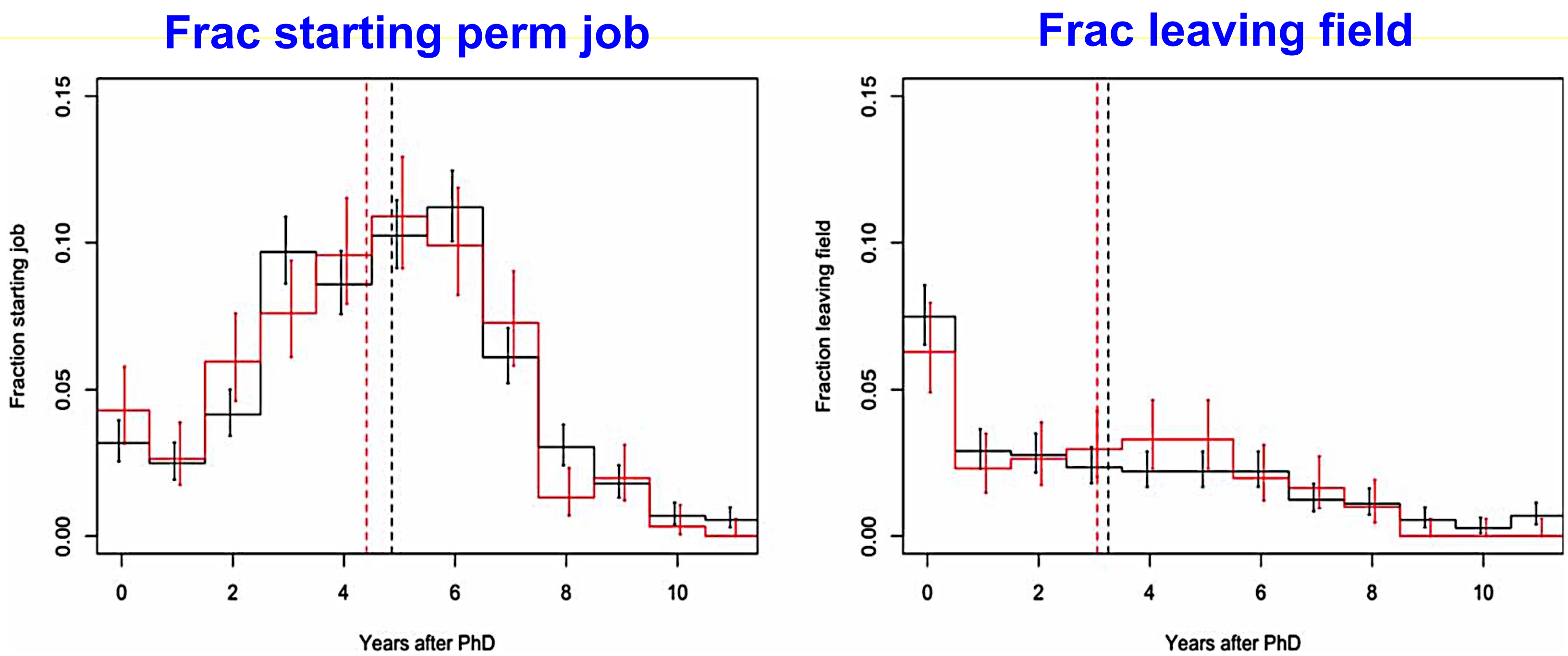
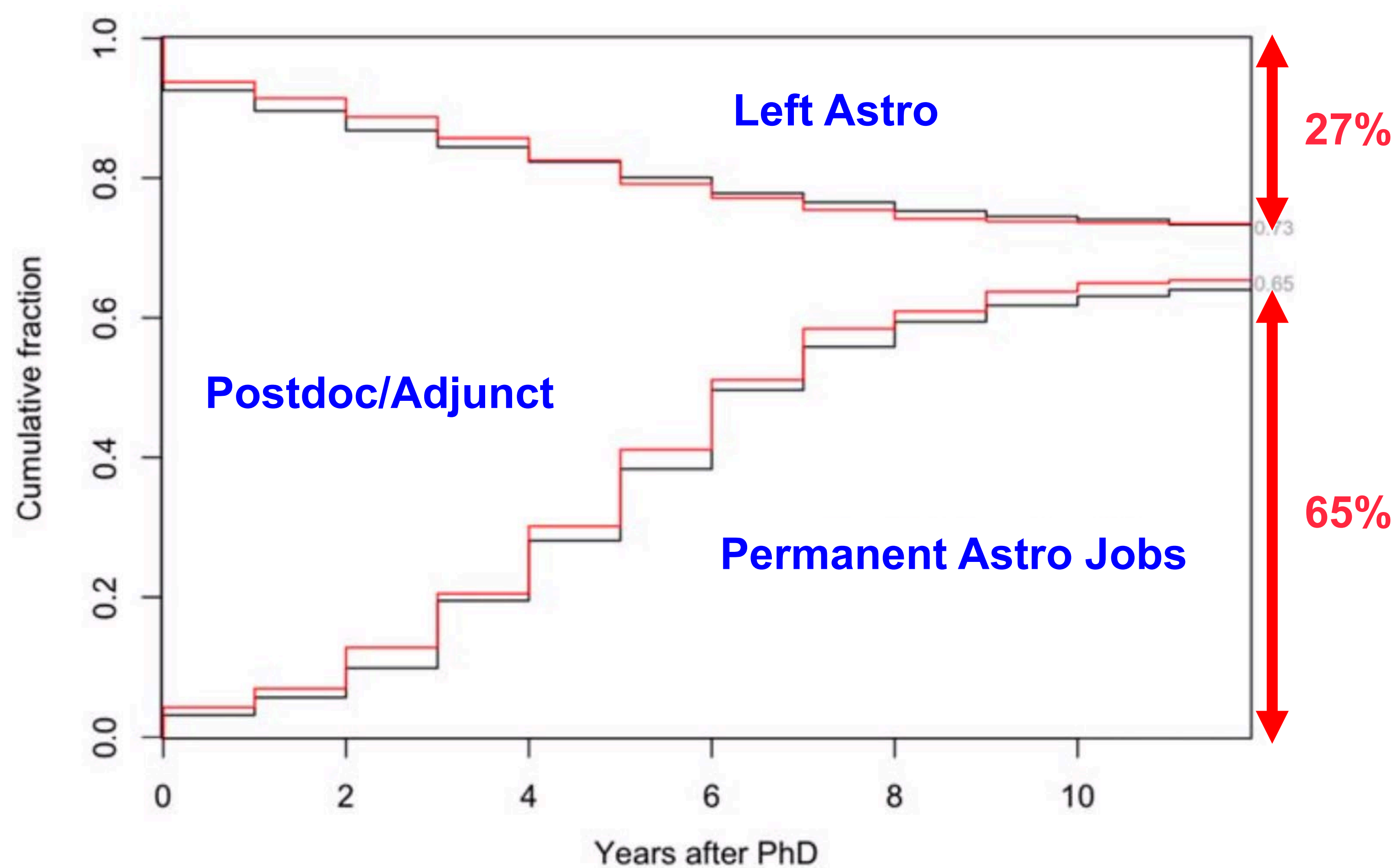


Figure 1. Histograms of recorded times (years after Ph.D.) at which Ph.D.s either: (left) progressed from term-limited to long-term or permanent positions within astronomy, or (right) left the field to pursue other employment. Histograms are normalized using total counts for each gender (regardless of outcome). Error bars show 67% binomial confidence intervals and dashed vertical lines show the means. Male astronomers are shown in black and female astronomers in red.

Perley 2019

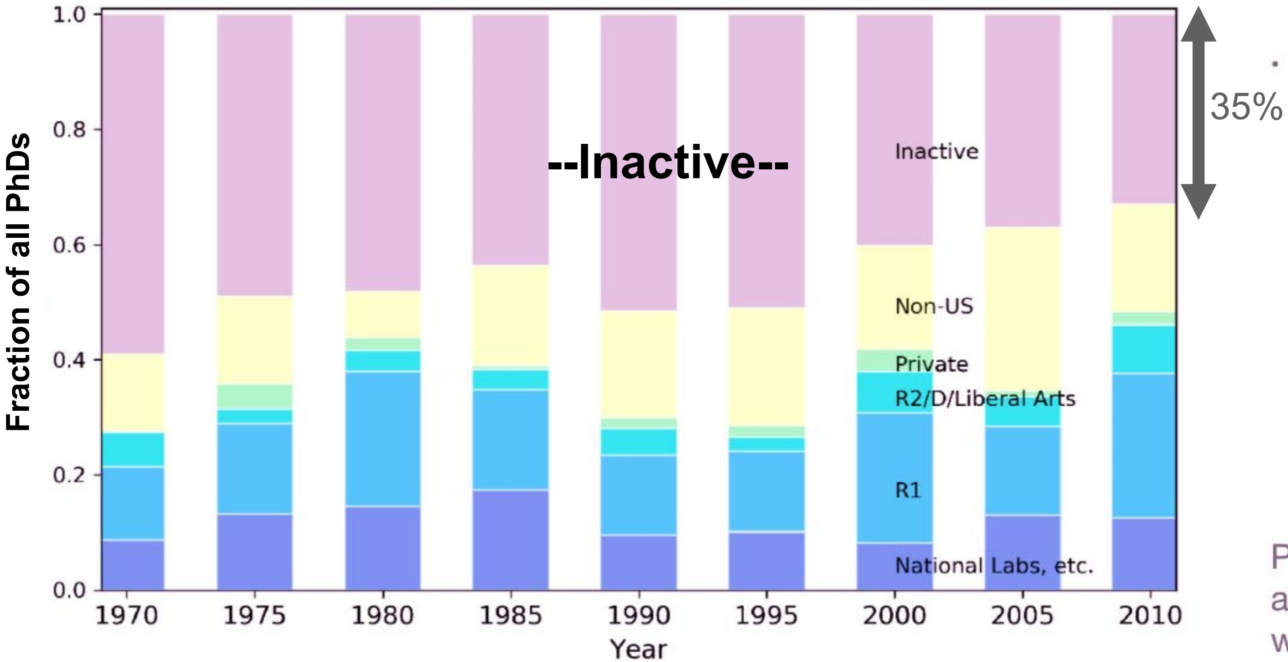
12-Year Cumulative Employment (Data 2000-2012)



Employment Demographics Studies

Momcheva 2019

"Active" = published in professional literature within 3 yrs



- Of all PhD recipients:
  - non-US: 18%
  - Private: 2%
  - R2, etc.: 5%
  - R1: 19%
  - National labs, etc.: 12%

PhD recipient find employment in a variety of different careers which require a range of skills.

Perley (2019): *"The number of astronomy PhD's is not greatly in excess of the number of careers available within the field."* [Data for 2000-2012]

Kamenetzky (2019): *"The overall number of potentially permanent positions...has slightly increased in the past decade [2010-2019] to ~380 per year compared to ~270 ten years earlier, roughly keeping pace with the increase in new PhDs."*

~ Permanent jobs in *astronomy*.

Perley (2019): *"The number of astronomy PhD's is n... in excess of the number of care... within the field."* [Data for 20...

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CONCLUDE: NOT GLOOMY, NOT FLUSH. TEMPERED OPTIMISM

Astronomy Long-term PhD Employment Pattern Through the 2000's:

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~1/3 Non Astronomy

(Faculty + Research Scientists: 65%)

(Perley 2019)

Positions Held by UVa Astro PhD's (1967-2017; 130 Degrees)

Faculty	33%
Research scientists	40%
Non-Astro	13%
Outreach	2%
Secondary ed	1%
Postdocs	11%

Numbers You Should Know
Part 2

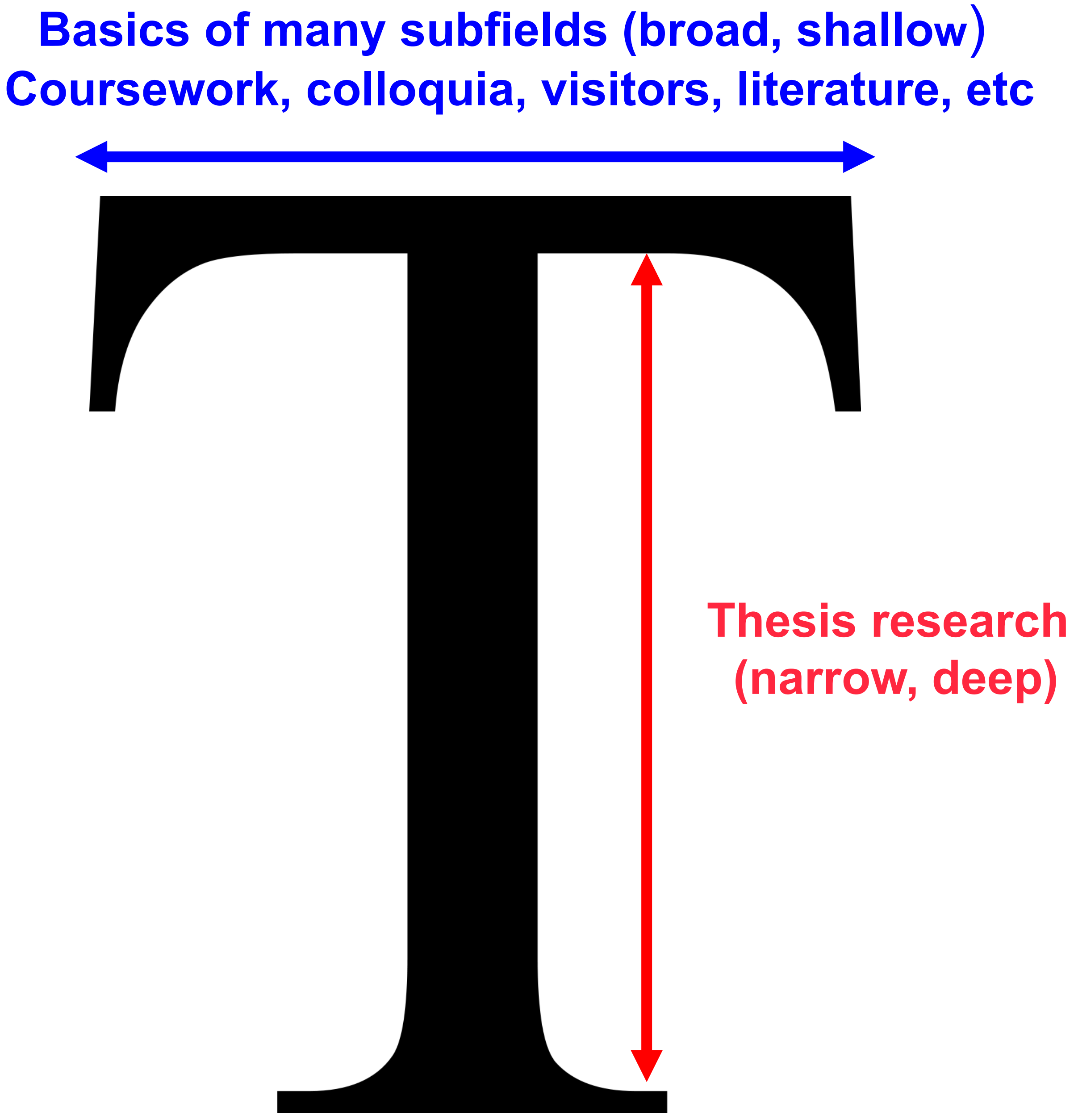
Professional effort

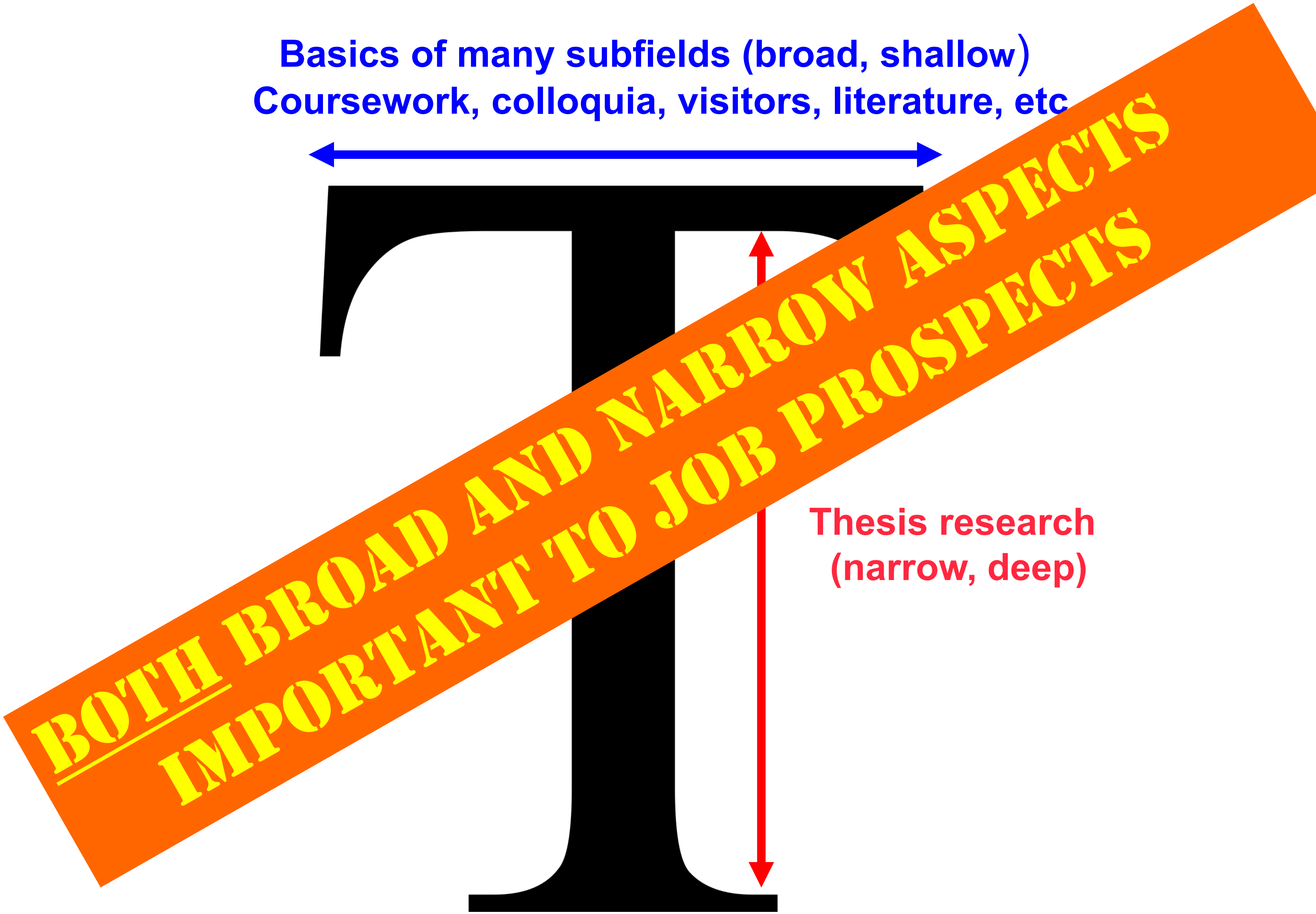
ASTR 8500 Spring 2022 Robert W. O'Connell

~95(?)%

95(?)% of astronomers love *most* of what they do

Life as a Graduate Student


Basics of many subfields (broad, shallow)
Coursework, colloquia, visitors, literature, etc
Thesis research
(narrow, deep)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T
Thesis research
(narrow, deep)
BOTH BROAD AND NARROW ASPECTS
IMPORTANT TO JOB PROSPECTS

10,000

= Number of HOURS of close engagement with a speciality before a person is ready to make important contributions

May involve actual *reconfiguration* of neural circuits(!)

10,000

= Number of HO… …engagement with a speci… …person is ready to make in… …butions

…actual *reconfiguration* of neural c…

FROM POP-PSYCHOLOGY

TAKE WITH GRAIN OF SALT

Life as a Faculty Member

13

~ # Responsibilities of a faculty member

Job Profile of a Faculty Member

- **Teaching**
  - Classroom teaching (mostly undergrad – 90-95% nonmajors)
  - Tutorial, small group instruction
  - Course, curriculum, & resource development/management
  - Student mentoring, advising, recommendations
  - Outreach
- **Research**
  - Personal **– undirected***
  - Supervising grad student & postdoc research
  - Management: lab/group direction, obtaining & administering finances (grants)
- **Service/Administration**
  - Local department & university administration: operations, governance, policies, personnel evaluation (recruiting, promotions)
  - Refereeing publications, proposal reviews
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- **Consulting**

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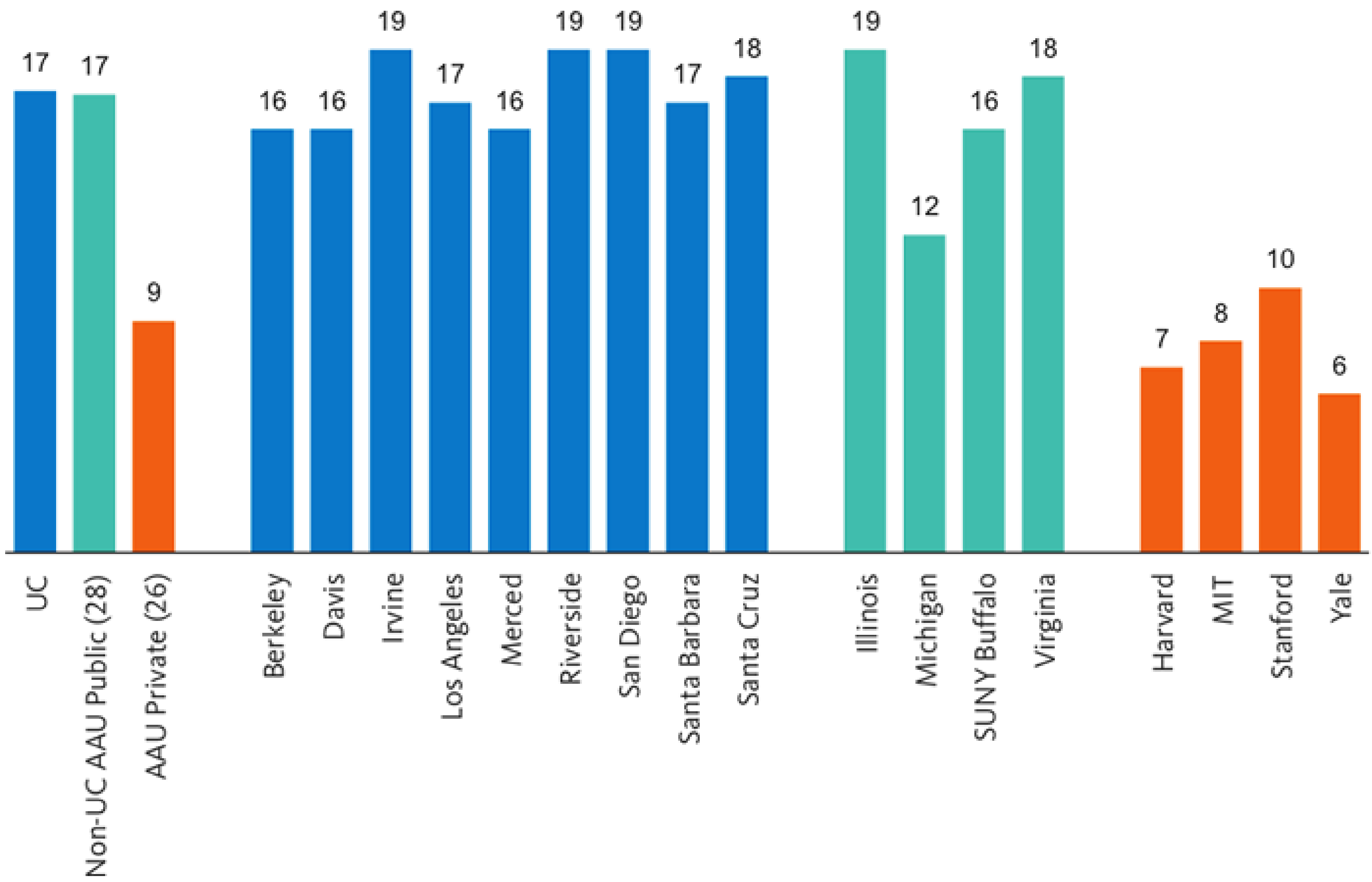
Almost no middle management

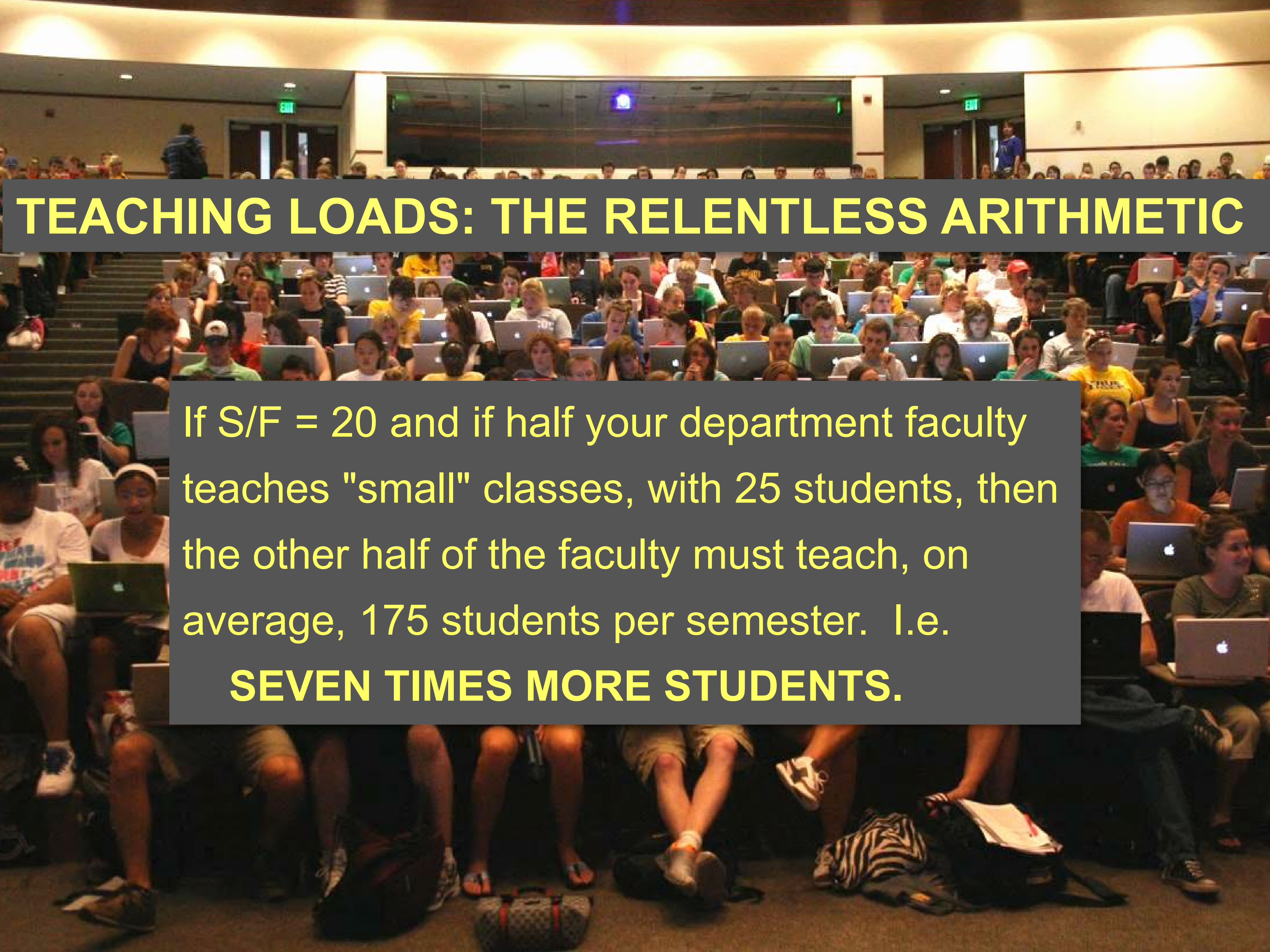
~90-200

= Number of UG students the average professor must teach each year

= 10 x S/F (in 3-credit classes)

Student/Faculty Ratios





TEACHING LOADS: THE RELENTLESS ARITHMETIC

If S/F = 20 and if half your department faculty teaches "small" classes, with 25 students, then the other half of the faculty must teach, on average, 175 students per semester. I.e.

SEVEN TIMES MORE STUDENTS.

~7:1

= Career averaged ratio of <u>total</u> teaching time to <u>in-class</u> time

Averaged effort for a 3-hour course: ~20 hours/wk

New burden for teachers!
Increasing emphasis on ELECTRONICS

* One hour of course video takes 50-100 hours of prep

1:1 to 3:1

= Ratio of real-time rehearsal to delivery time for a well-prepped talk

- An important class lecture
- A job talk
- A review talk
- A news conference
- etc

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OPTIONAL TOPIC: "HOW TO GIVE A BAD TALK"

- An important class lecture
- A job talk
- A review talk
- A news conference
- etc

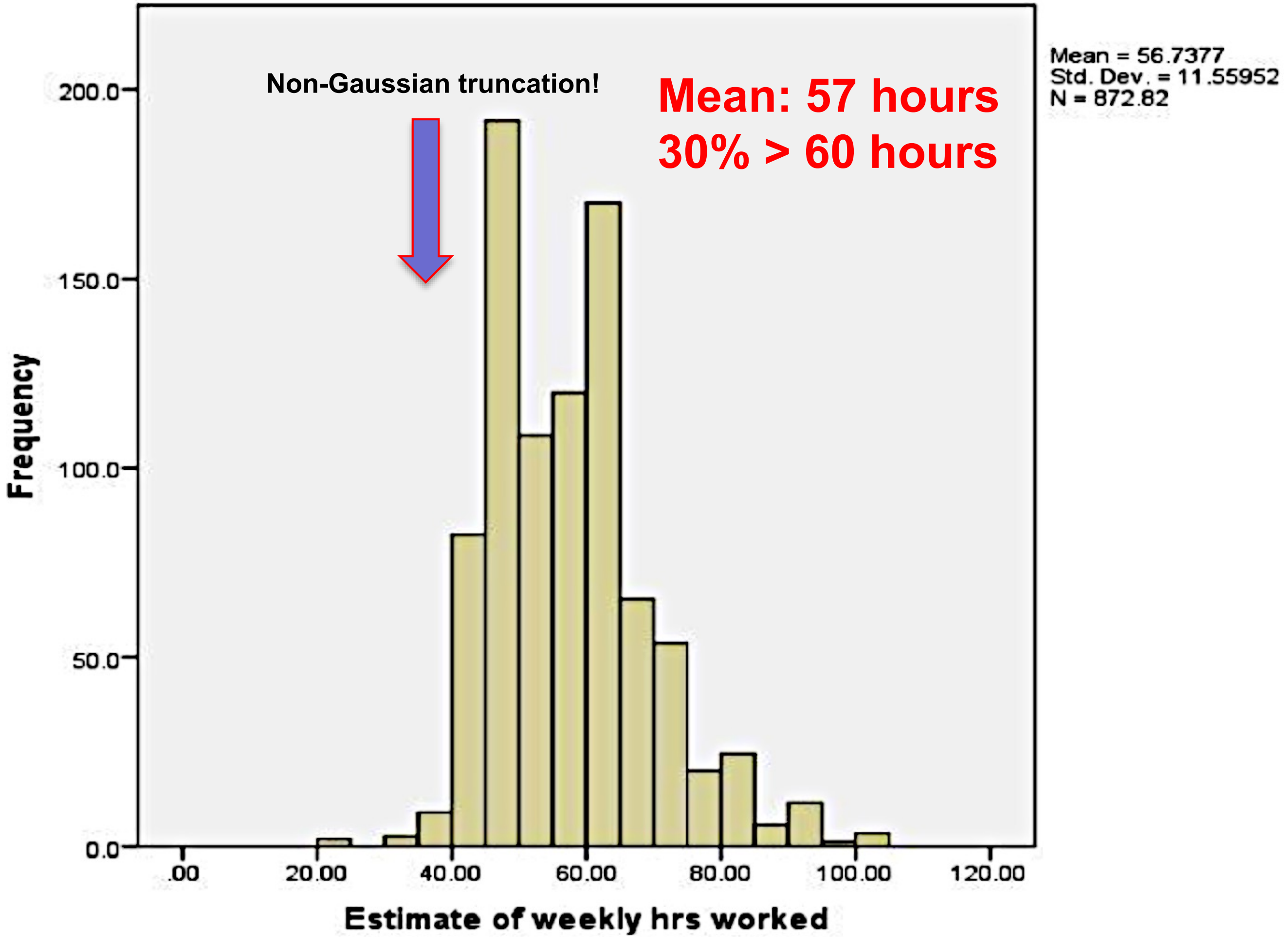

MUST PLAN FOR HEAVY DEMANDS
OF TEACHING ON YOUR TIME
MIZZOU

~55

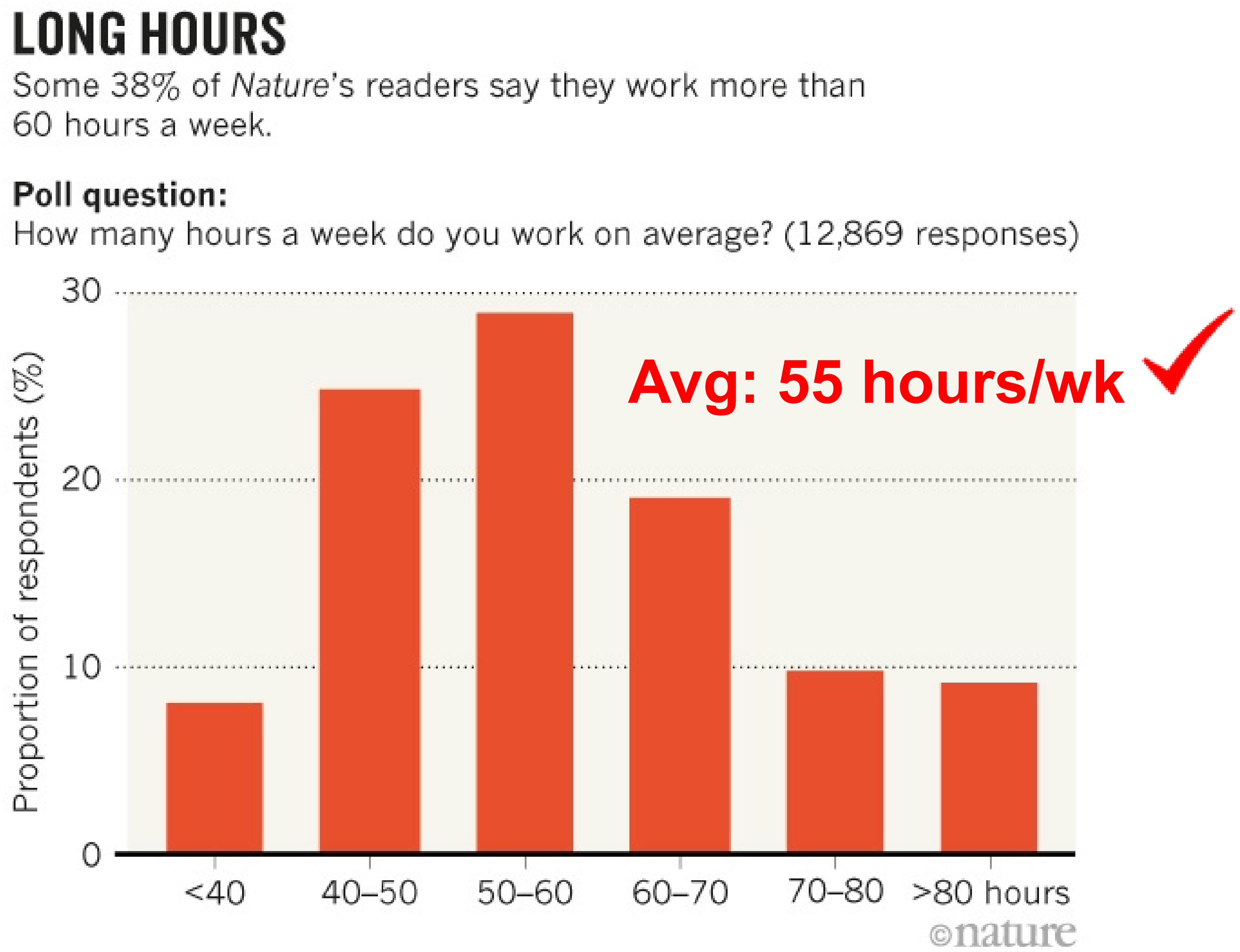
= Number of hours per week professors *claim* to work

UVa Faculty Senate Survey (2012)

Figure VII-1: Frequency Distribution of Hours Worked Per Week, Full Time Faculty Only.



Scientist Survey: Hours Worked (Nature)



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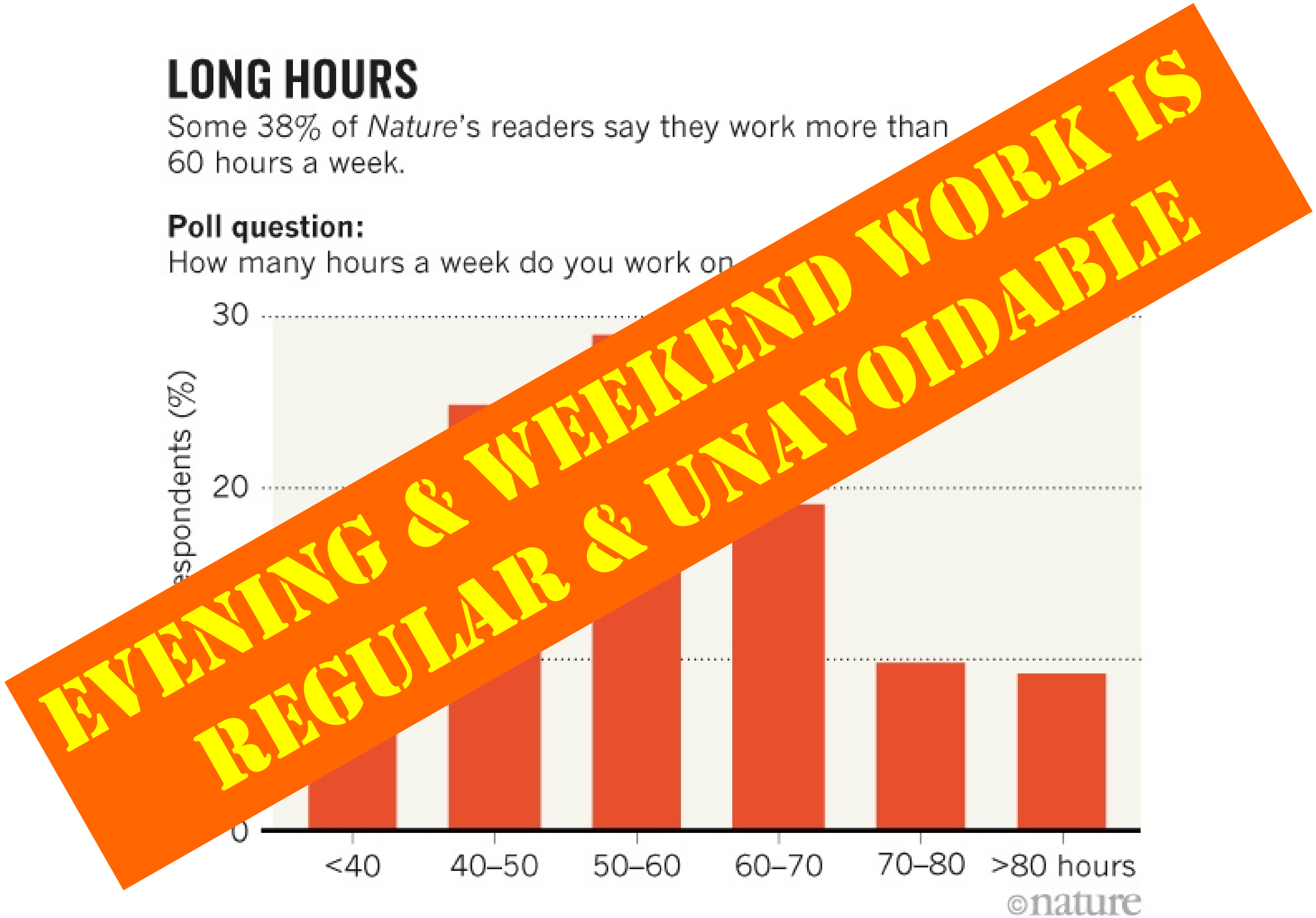

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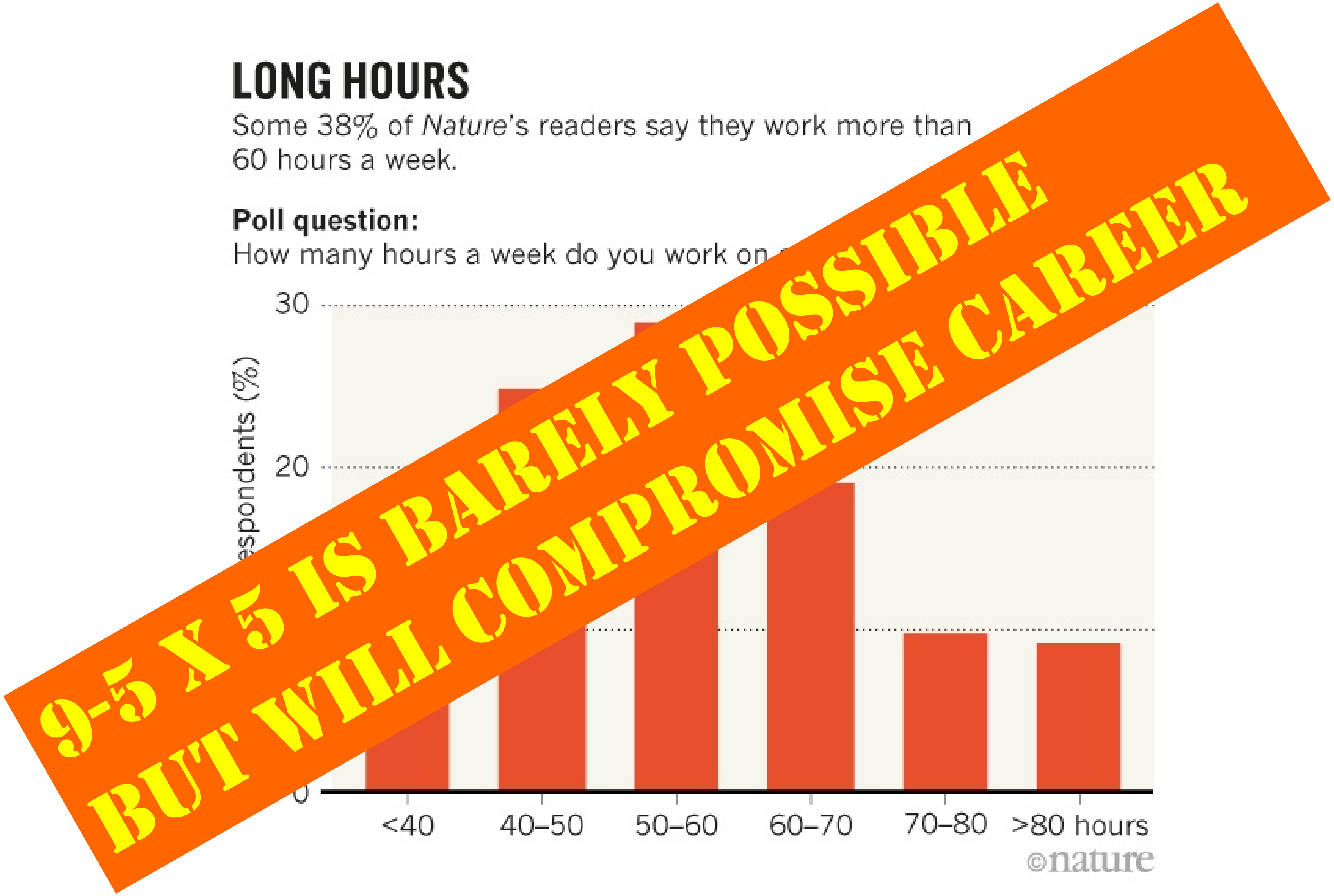

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TIME MANAGEMENT IS AN ESSENTIAL SKILL

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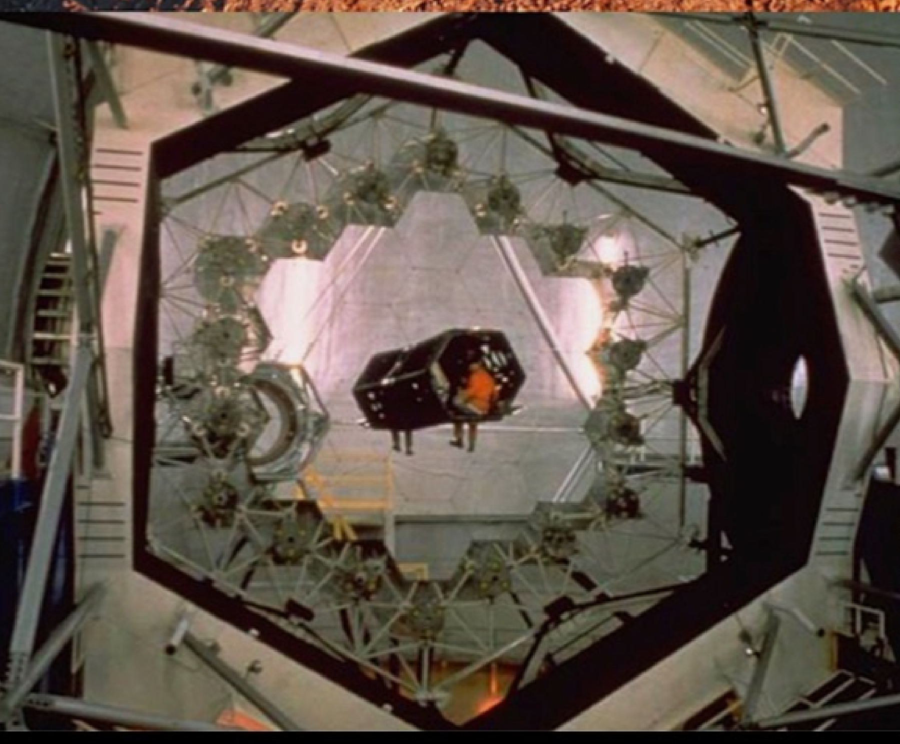
  - Loc [illegible] istration: operations, governance, policies, p [illegible] ng, promotions)
  - Refe [illegible] proposal reviews
  - Discipl [illegible] s, planning, meetings, advocacy
  - National [illegible] y policy, planning, review
- Consulting

OPTIONAL TOPIC:
"MANAGING YOUR TIME"

Life as a Research Scientist



Job Profile of a Research Scientist

- Research Support
  - Observer support & training
  - Telescope time allocation
  - Software design, development, oversight
  - Data analysis pipelines, data archives, quality assurance
  - Instrumentation development
  - Documentation
  - Facility upgrade projects
  - Policy formulation
  - Personnel administration
- Personal Research
  - Allocation usually specified; typically 15-50% but wide variation
  - Grant support provides buy-outs of service time
- General Service
  - Refereeing publications, proposal reviews
  - Disciplinary activities, planning, meetings, advocacy
  - National agency policy, planning, review
- Consulting

Job Profile of a Research Scientist

- Main occupational hazard of a research scientist?

Meetings

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(Faculty + Research Scientists: 65%)

(Perley 2019)

"Non-Dedicated Astronomy"

Jobs drawing on general training in high-tech field

Examples:

- Space science/applications (govt, contractors, commercial)
- High-end computing (databases, AI)
- Computational biology (genomics, neurology)
- Communications (radio, microwave, fiber/laser)
- Instrumentation (sensors, imaging, optics)
- Medical imaging

→ **Be alert for opportunities to develop transferable knowledge and skills**

3611

= Largest number of authors on an astronomical paper

The Rise of Group Science

ADS Statistics on published Ast/Ap papers

# Authors	1975	2016
1	40%	7%
>2	26%	78%
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Multi-messenger Observations of a Binary Neutron Star Merger*

LIGO Scientific Collaboration and Virgo Collaboration, Fermi GBM, INTEGRAL, IceCube Collaboration, AstroSat Cadmium Zinc Telluride Imager Team, IPN Collaboration, The Insight-HXMT Collaboration, ANTARES Collaboration, The Swift Collaboration, AGILE Team, The 1M2H Team, The Dark Energy Camera GW-EM Collaboration and the DES Collaboration, The DLT40 Collaboration, GRAWITA: GRAvitational Wave Inaf TeAm, The Fermi Large Area Telescope Collaboration, ATCA: Australia Telescope Compact Array, ASKAP: Australian SKA Pathfinder, Las Cumbres Observatory Group, OzGrav, DWF (Deeper, Wider, Faster Program), AST3, and CAASTRO Collaborations, The VINROUGE Collaboration, MASTER Collaboration, J-GEM, GROWTH, JAGWAR, Caltech-NRAO, TTU-NRAO, and NuSTAR Collaborations, Pan-STARRS, The MAXI Team, TZAC Consortium, KU Collaboration, Nordic Optical Telescope, ePESSTO, GROND, Texas Tech University, SALT Group, TOROS: Transient Robotic Observatory of the South Collaboration, The BOOTES Collaboration, MWA: Murchison Widefield Array, The CALET Collaboration, IKI-GW Follow-up Collaboration, H.E.S.S. Collaboration, LOFAR Collaboration, LWA: Long Wavelength Array, HAWC Collaboration, The Pierre Auger Collaboration, ALMA Collaboration, Euro VLBI Team, Pi of the Sky Collaboration, The Chandra Team at McGill University, DFN: Desert Fireball Network, ATLAS, High Time Resolution Universe Survey, RIMAS and RATIR, and SKA South Africa/MeerKAT
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GROUPS, not people

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Abstract

On 2017 August 17 a binary neutron star coalescence candidate (later designated GW170817) with merger time 12:41:04 UTC was observed through gravitational waves by the Advanced LIGO and Advanced Virgo detectors. The *Fermi* Gamma-ray Burst Monitor independently detected a gamma-ray burst (GRB 170817A) with a time delay of $\sim$1.7 s with respect to the merger time. From the gravitational-wave signal, the source was initially localized to a sky region of 31 deg^2 at a luminosity distance of 40^{+8}_{-8} Mpc and with component masses consistent with neutron stars. The component masses were later measured to be in the range 0.86 to 2.26 $M_\odot$. An extensive observing campaign was launched across the electromagnetic spectrum leading to the discovery of a bright optical transient (SSS17a, now with the IAU identification of AT 2017gfo) in NGC 4993 (at $\sim$40 Mpc) less than 11 hours after the merger by the One-Meter, Two Hemisphere (1M2H) team using the 1 m Swope Telescope. The optical transient was independently detected by multiple teams within an hour. Subsequent observations targeted the object and its environment. Early ultraviolet observations revealed a blue transient that faded within 48 hours. Optical and infrared observations showed a redward evolution over $\sim$10 days. Following early non-detections, X-ray and radio emission were discovered at the transient's position $\sim$9 and $\sim$16 days, respectively, after the merger. Both the X-ray and radio emission likely arise from a physical process that is distinct from the one that generates the UV/optical/near-infrared emission. No ultra-high-energy gamma-rays and no neutrino candidates consistent with the source were found in follow-up searches. These observations support the hypothesis that GW170817 was produced by the merger of two neutron stars in NGC 4993 followed by a short gamma-ray burst (GRB 170817A) and a kilonova/macronova powered by the radioactive decay of *r*-process nuclei synthesized in the ejecta.

Key words: gravitational waves – stars: neutron

1. Introduction

Over 80 years ago Baade & Zwicky (1934) proposed the idea of neutron stars, and soon after, Oppenheimer & Volkoff (1939) carried out the first calculations of neutron star models. Neutron stars entered the realm of observational astronomy in the 1960s by providing a physical interpretation of X-ray emission from Scorpius X-1 (Giacconi et al. 1962; Shklovsky 1967) and of radio pulsars (Gold 1968; Hewish et al. 1968; Gold 1969).

The discovery of a radio pulsar in a double neutron star system by Hulse & Taylor (1975) led to a renewed interest in binary stars and compact-object astrophysics, including the development of a scenario for the formation of double neutron stars and the first population studies (Flannery & van den Heuvel 1975; Massevitch et al. 1976; Clark 1979; Clark et al. 1979; Dewey & Cordes 1987; Lipunov et al. 1987; for reviews see Kalogera et al. 2007; Postnov & Yungelson 2014). The Hulse-Taylor pulsar provided the first firm evidence (Taylor & Weisberg 1982) of the existence of gravitational waves (Einstein 1916, 1918) and sparked a renaissance of observational tests of general relativity (Damour & Taylor 1991, 1992; Taylor et al. 1992; Wex 2014). Merging binary neutron stars (BNSs) were quickly recognized to be promising sources of detectable gravitational waves, making them a primary target for ground-based interferometric detectors (see Abadie et al. 2010 for an overview). This motivated the development of accurate models for the two-body, general-relativistic dynamics (Blanchet et al. 1995; Buonanno & Damour 1999; Pretorius 2005; Baker et al. 2006; Campanelli et al. 2006; Blanchet 2014) that are critical for detecting and interpreting gravitational waves (Abbott et al. 2016c, 2016d, 2016e, 2017a, 2017c, 2017d).

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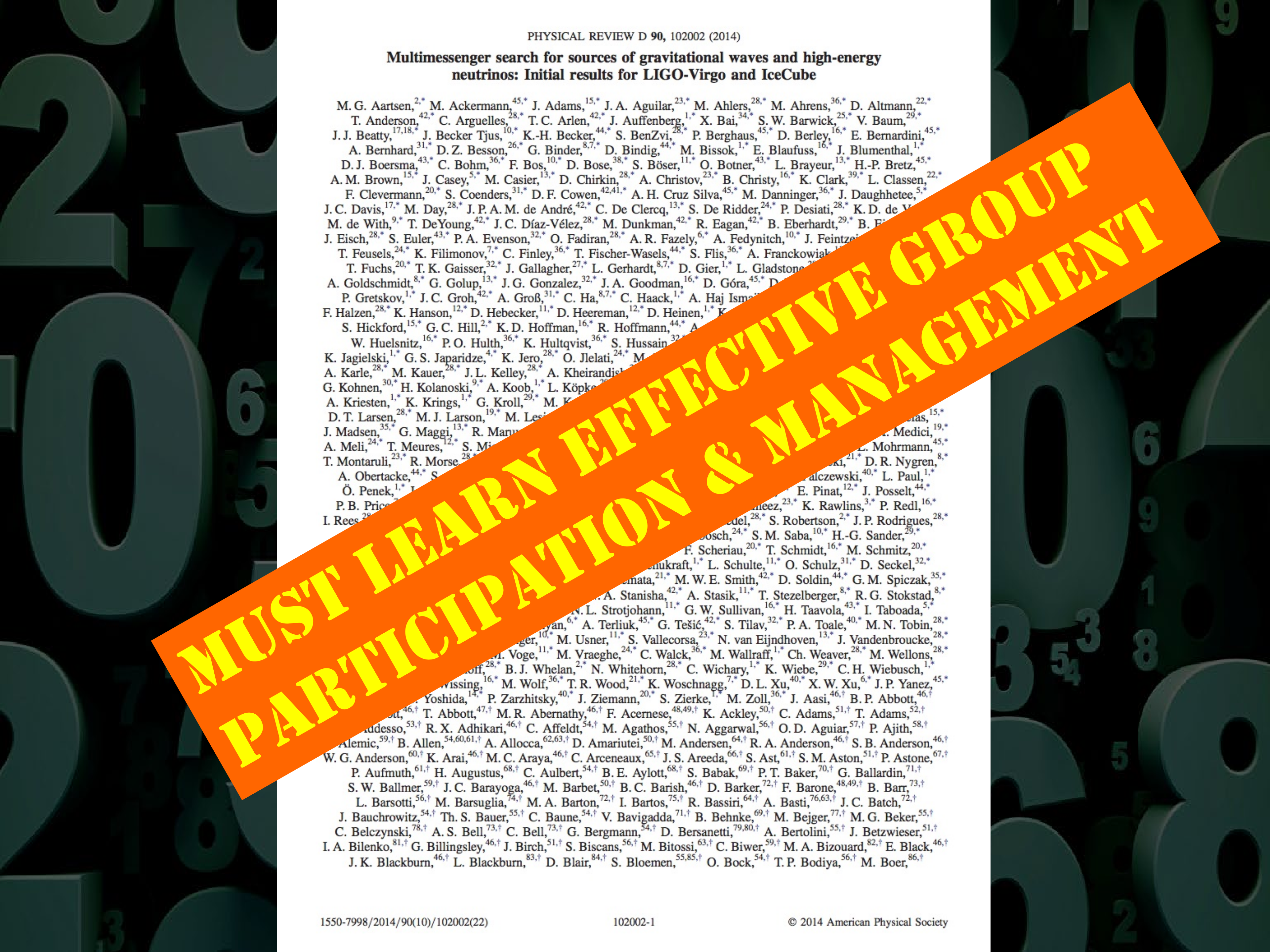
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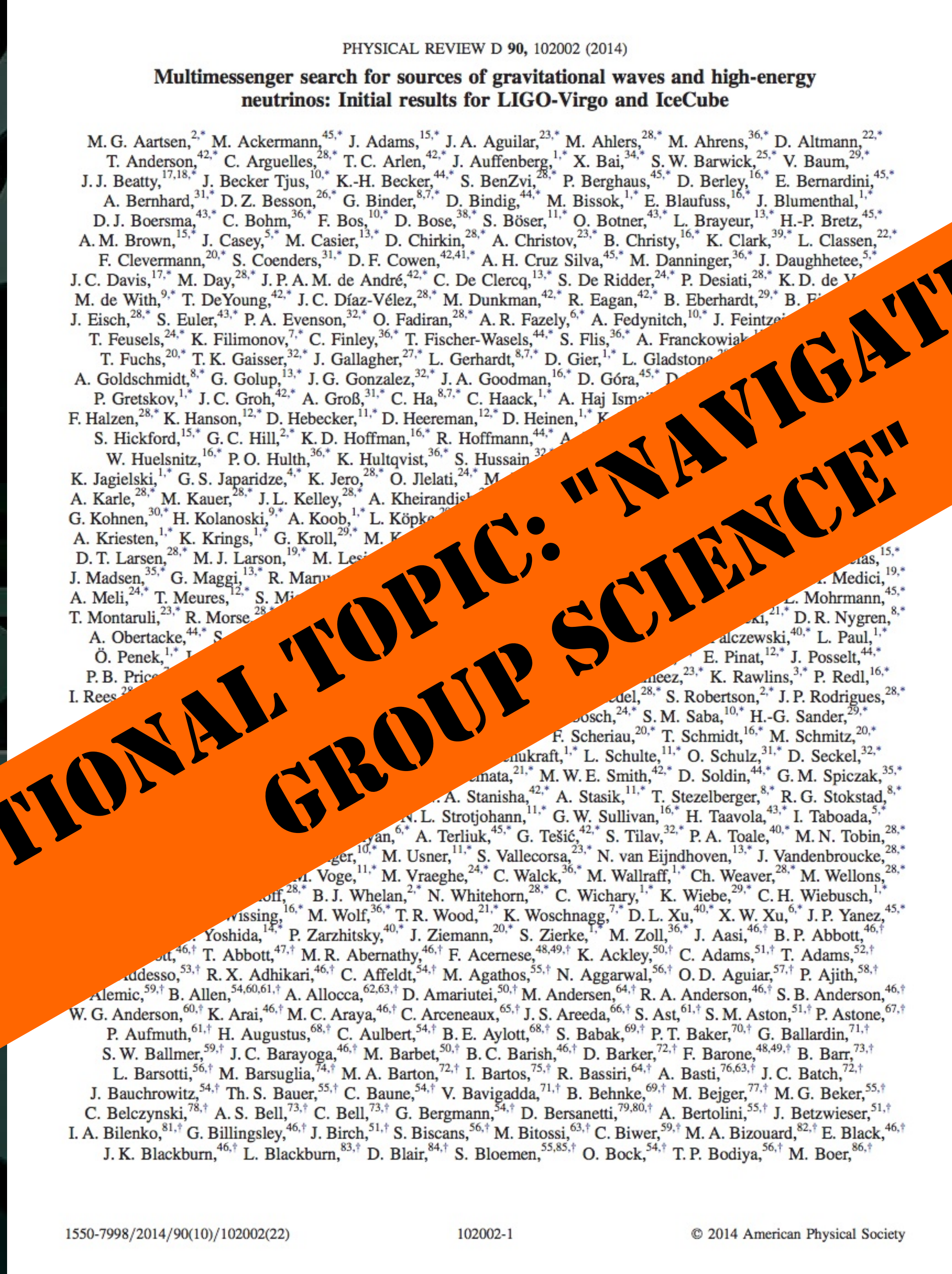

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