

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

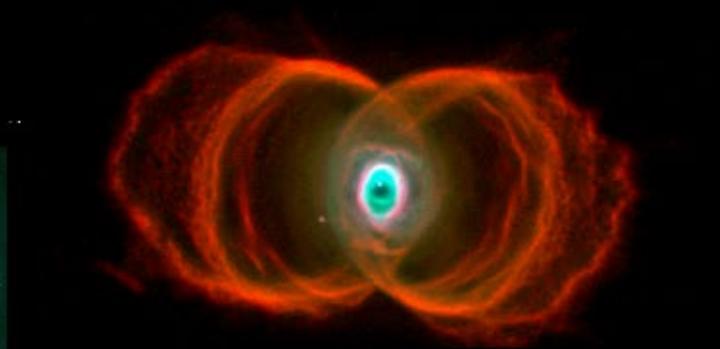
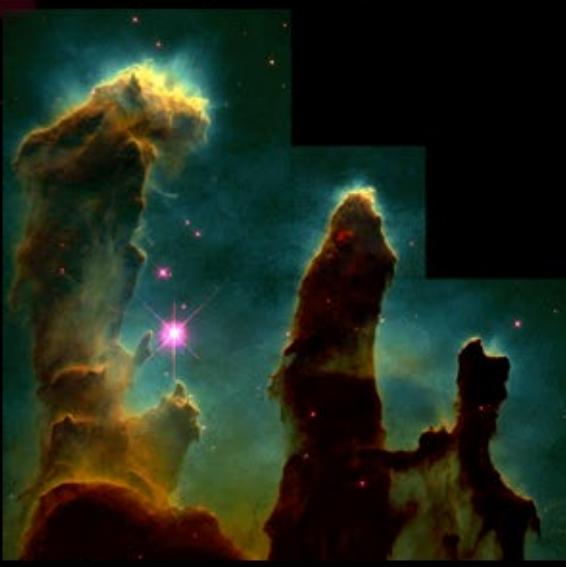
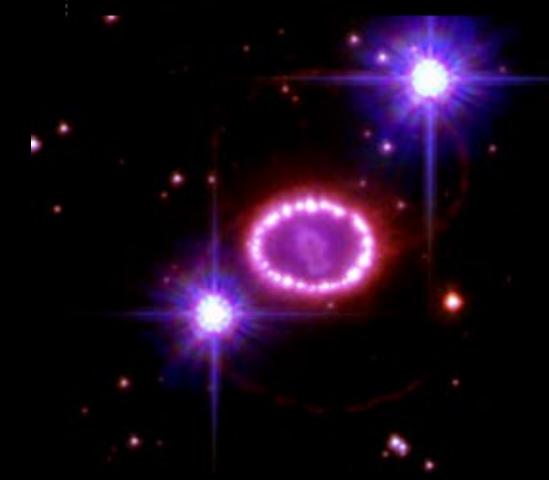
#2 Environment

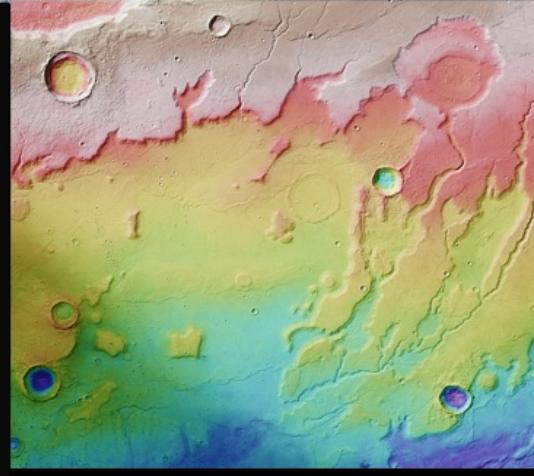
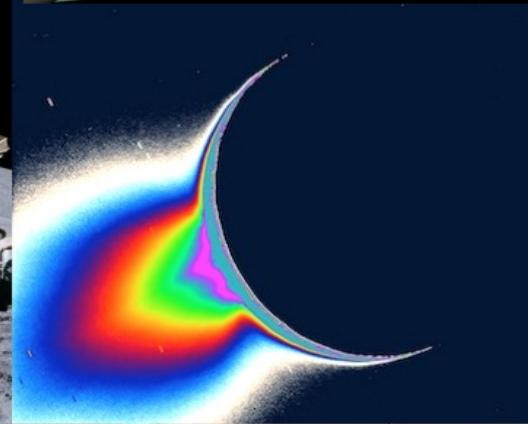
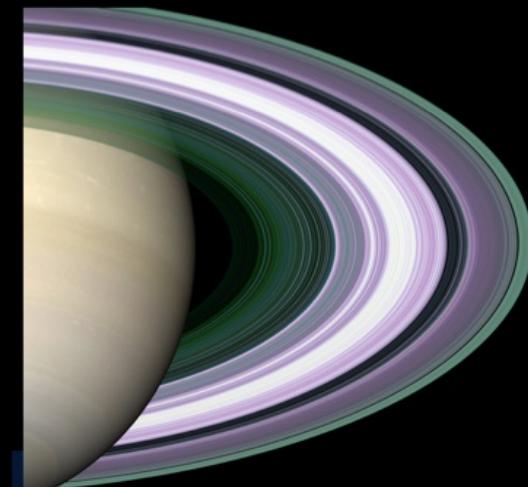
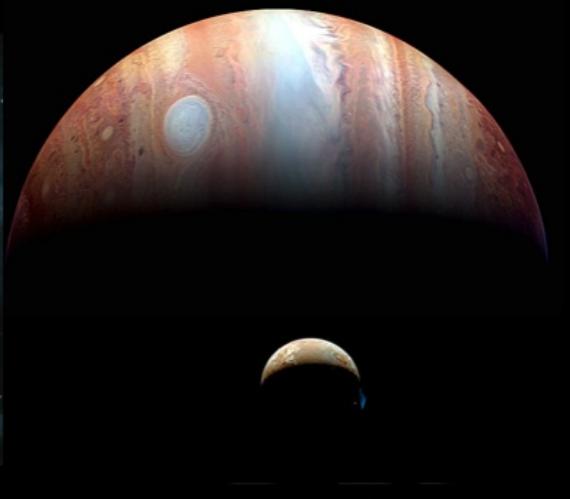
#3 Astronomy & Space

We're #1 in impact
per practitioner!

Total STEMM employment: 16 million

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



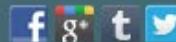


SUN 9/8c MAR 9

COSMOS: A SPACETIME ODYSSEY

Presented by FOX Sun 9/8c and National Geographic Mon 10/9c

Blog Clips Live Event

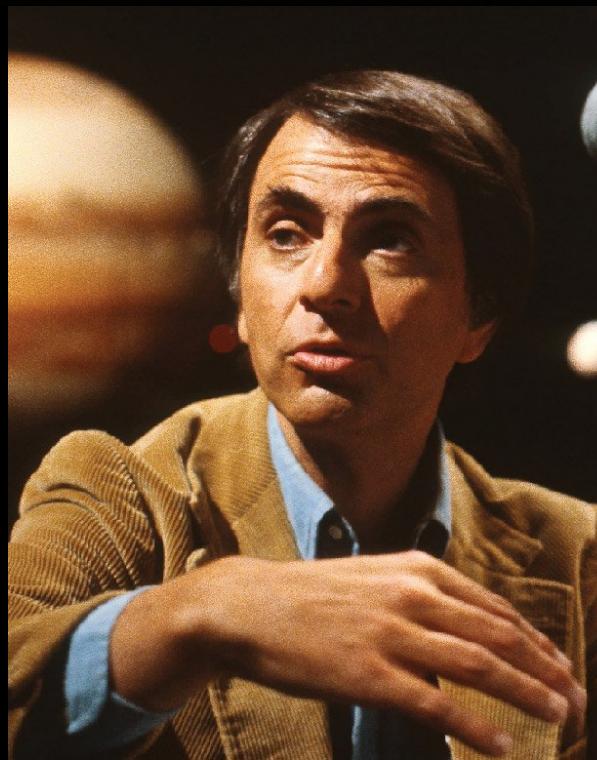


Samsung GALAXY

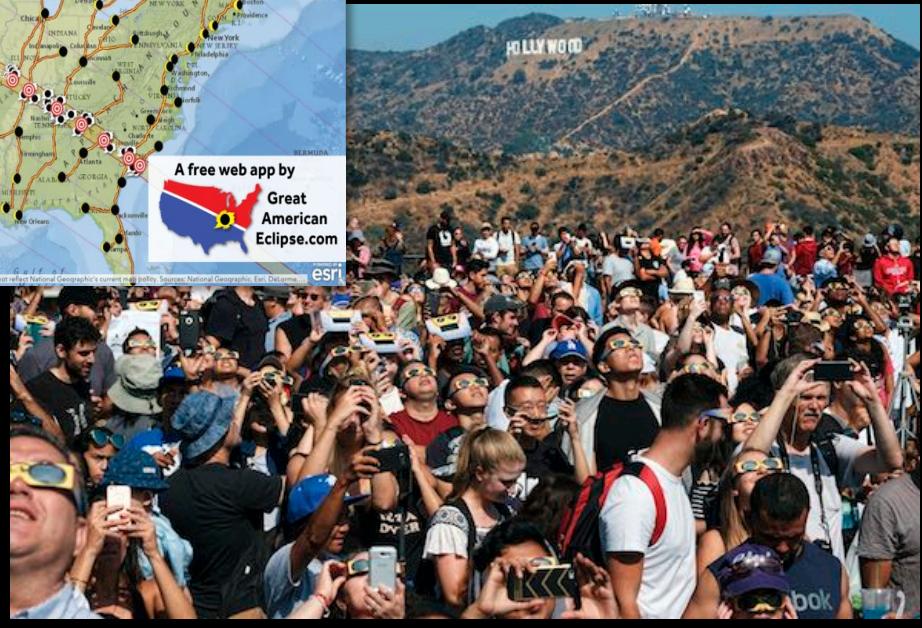
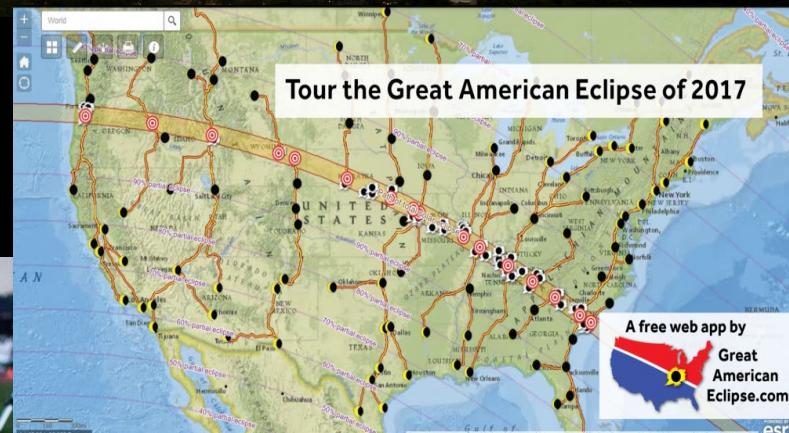
Jeep



AN EPIC
ADVENTURE IN TIME,
SPACE AND LIFE.



Eclipse USA 2017



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.

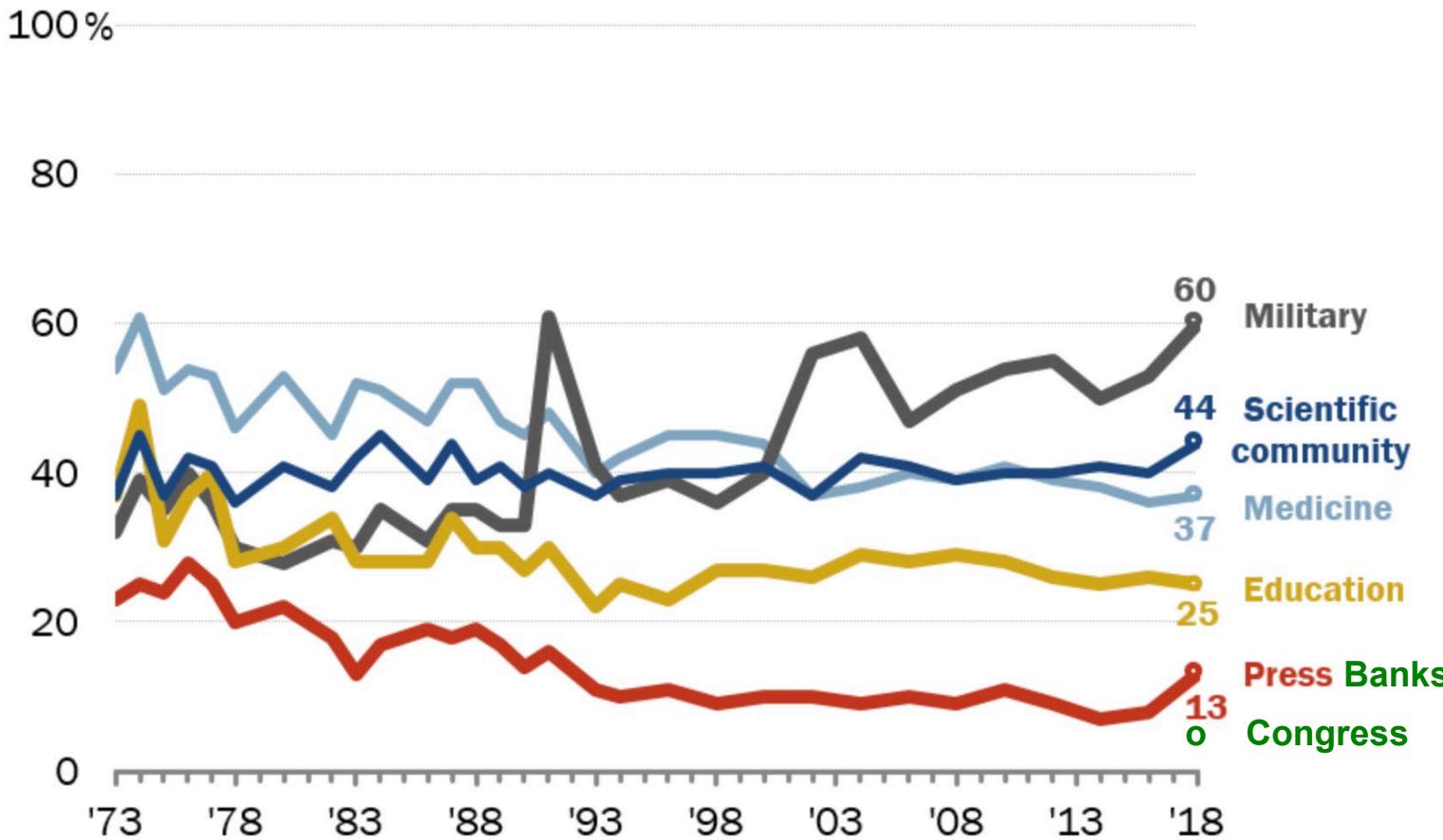


**"Scientist" is the #4 most
prestigious profession**

(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.

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.

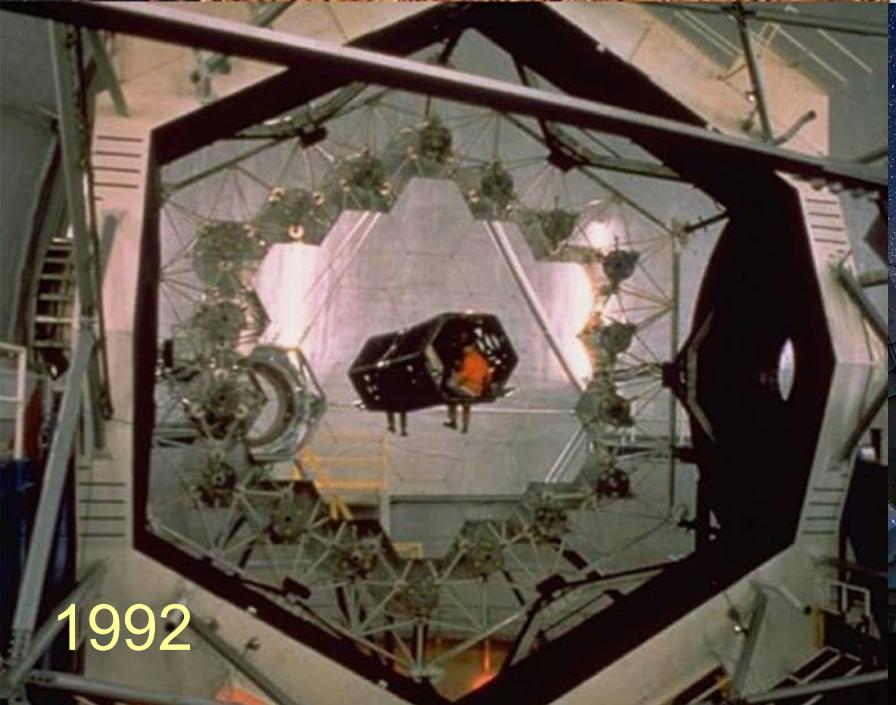
***AAS membership, 2016



\$425,000

= National budget for astronomy
per astronomer

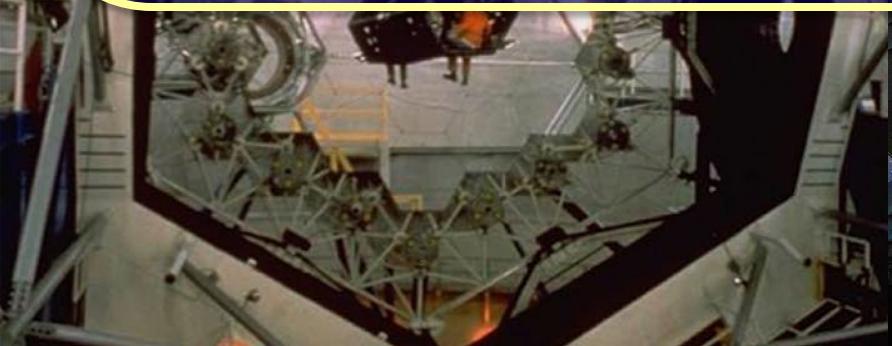
...BUT: mostly in the form of shared
observing facilities





Astronomy is ~uniquely dependent on
large, shared experimental facilities

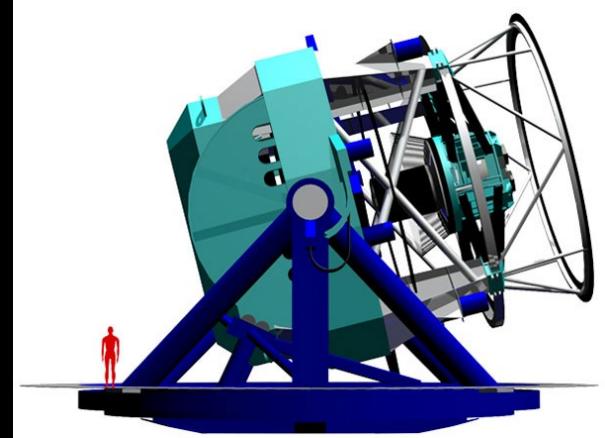
Astronomical facilities have long
productive lifetimes; a blessing & a curse



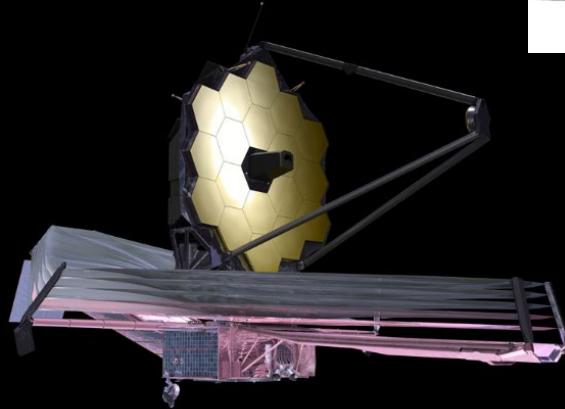
Promise of the Next Decade



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, STScl, 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

65%

(Perley 2019)

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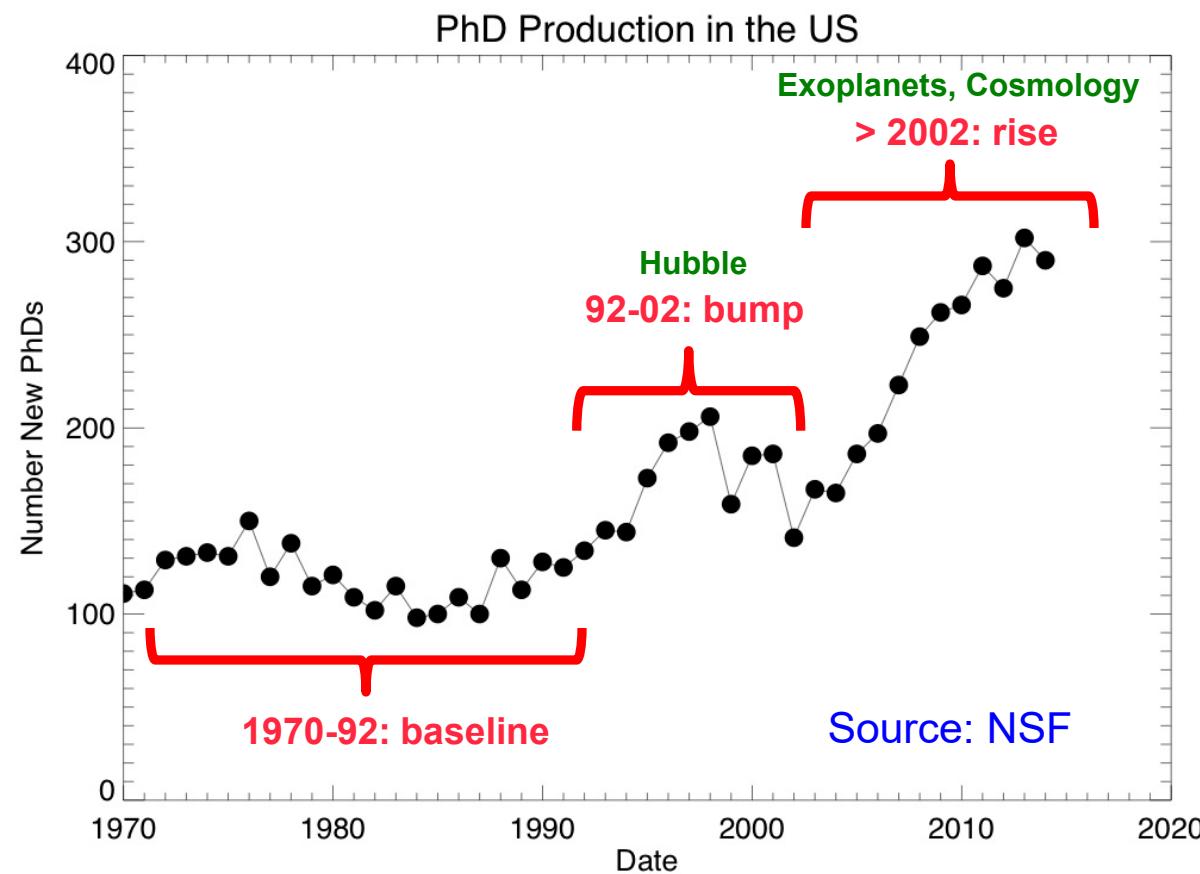
(Perley 2019)

How many jobs?

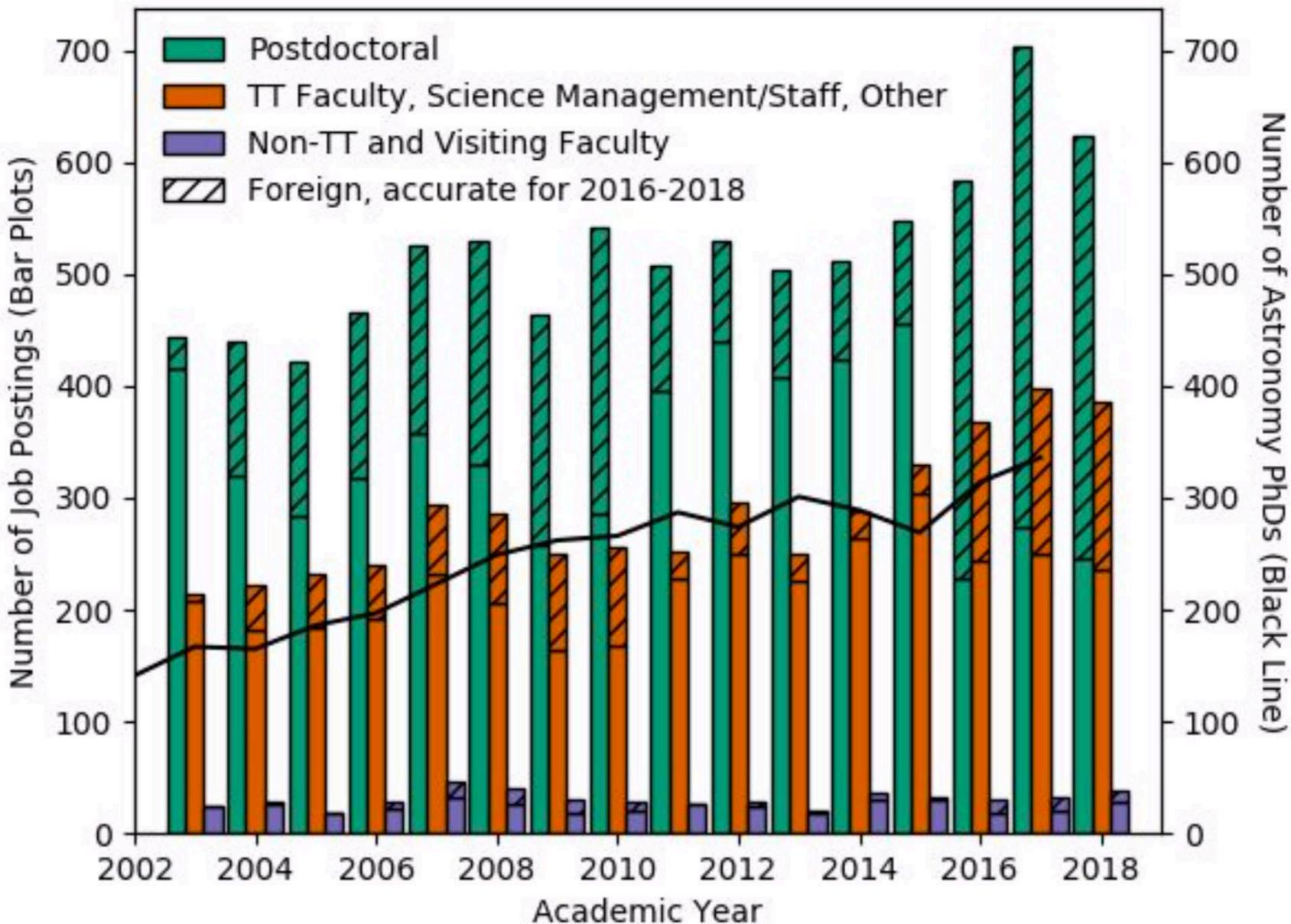
~8500

- = Membership of AAS + Nonmembers
- Non-grad degrees

Production of New Astronomy PhD's



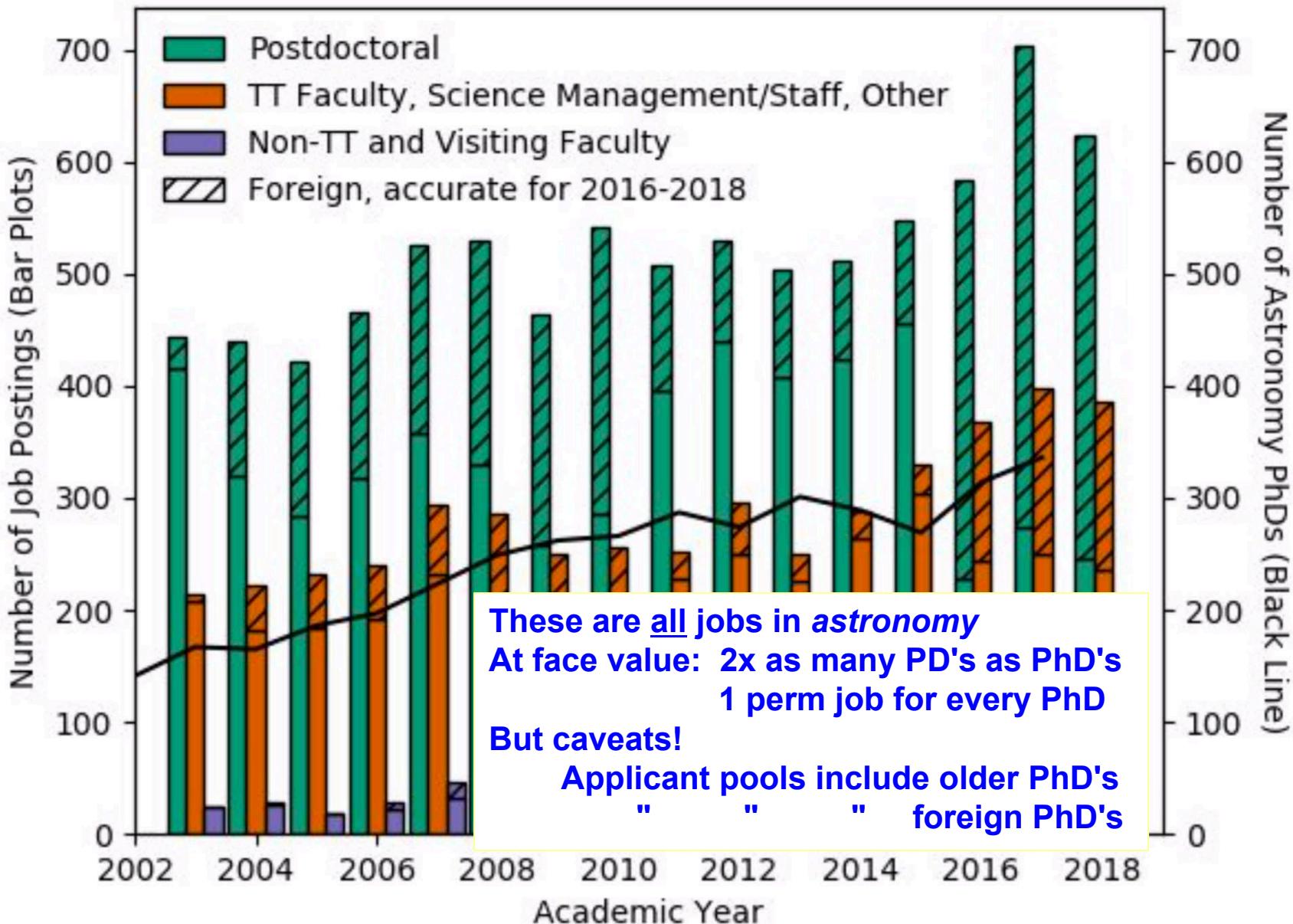
AAS Job Register Statistics



Black line: PhD's produced

(Kamenetzky, White Paper, 2019)

AAS Job Register Statistics



Black line: PhD's produced

(Kamenetzky, White Paper, 2019)

Employment Demographics Studies

Perley 2019

Publications of the Astronomical Society of the Pacific, 131:114502 (7pp), 2019 November

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<https://doi.org/10.1088/1538-3873/ab0ec4>



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

Perley 2019

Publications of the Astronomical Society of the Pacific, 131:114502 (7pp), 2019 November

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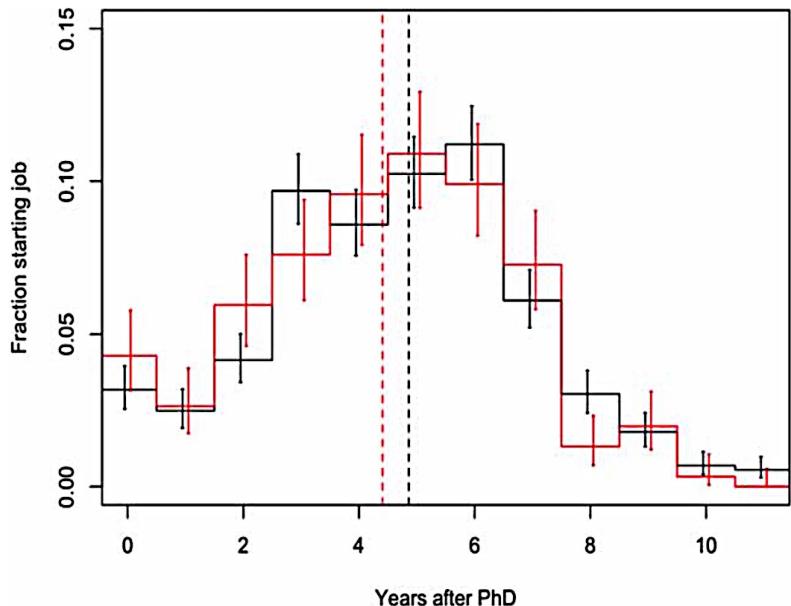
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Followed actual post-PhD histories of over 1100 individual astronomers, unlike earlier studies using broad statistical measures or unreliable reporting (e.g. the "Rumor Mill" site).

Data for 2000-2012.

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

Frac starting perm job



Frac leaving field

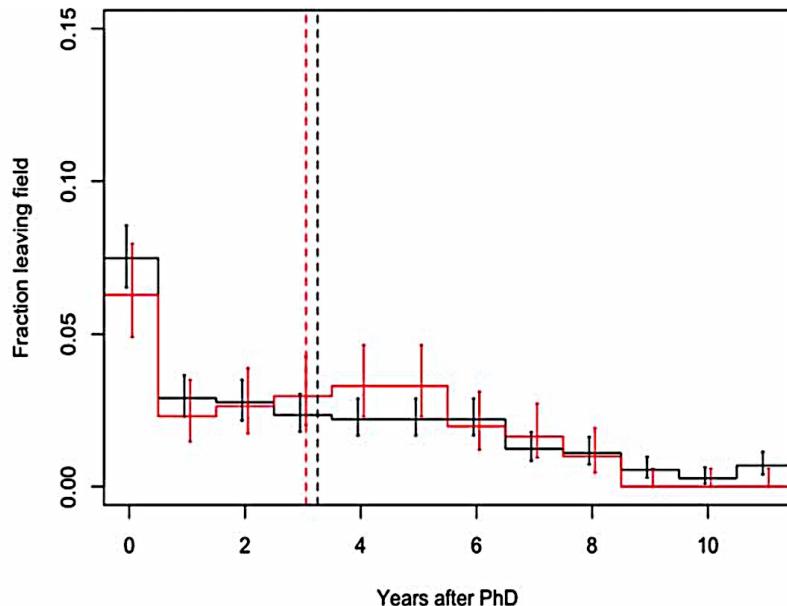
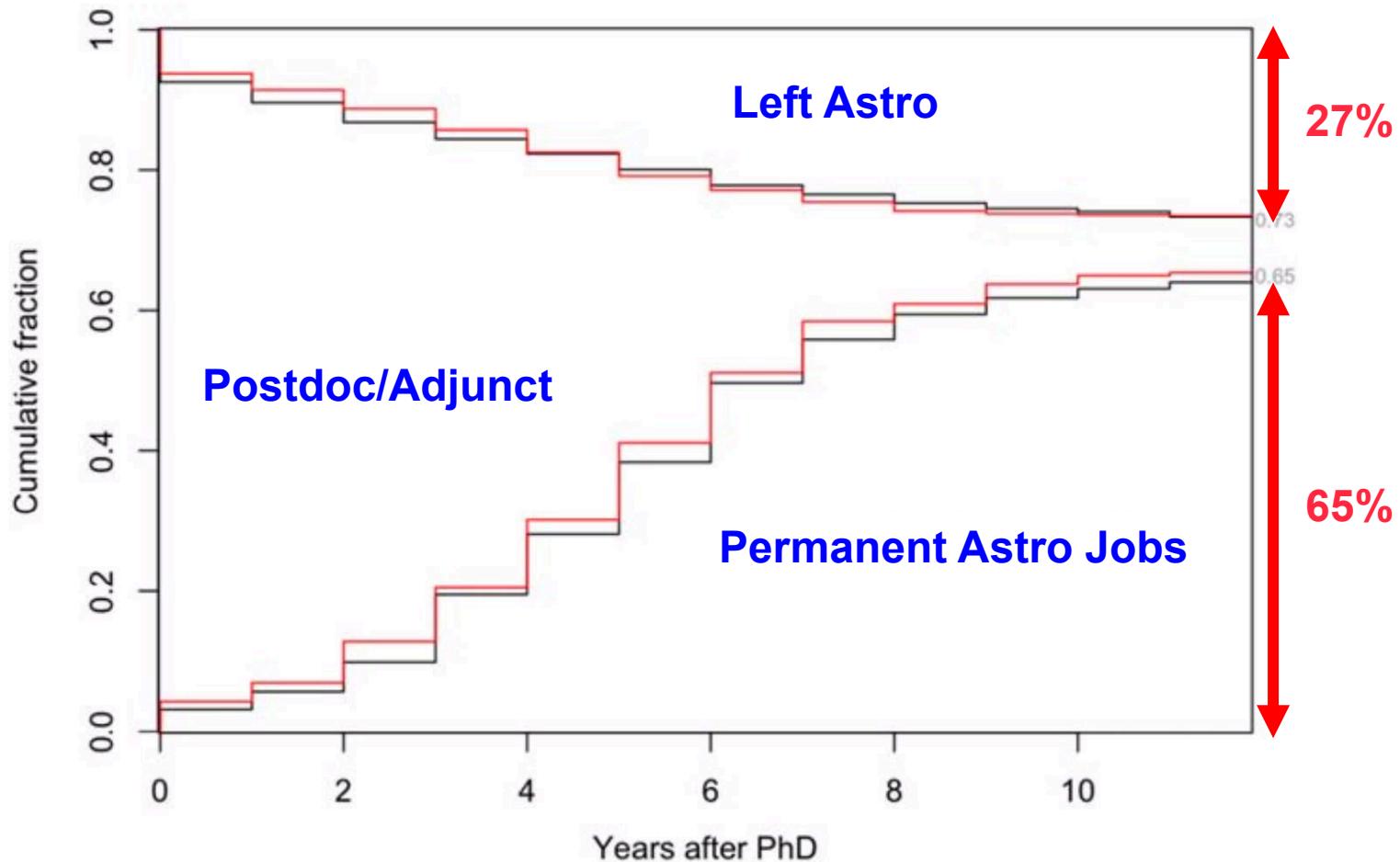


Figure 1. Histograms of recorded times (years after Ph.D.) at which Ph.D.s either: (left) progressed from term-limited to long-term or permanent positions within astronomy, or (right) left the field to pursue other employment. Histograms are normalized using total counts for each gender (regardless of 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.

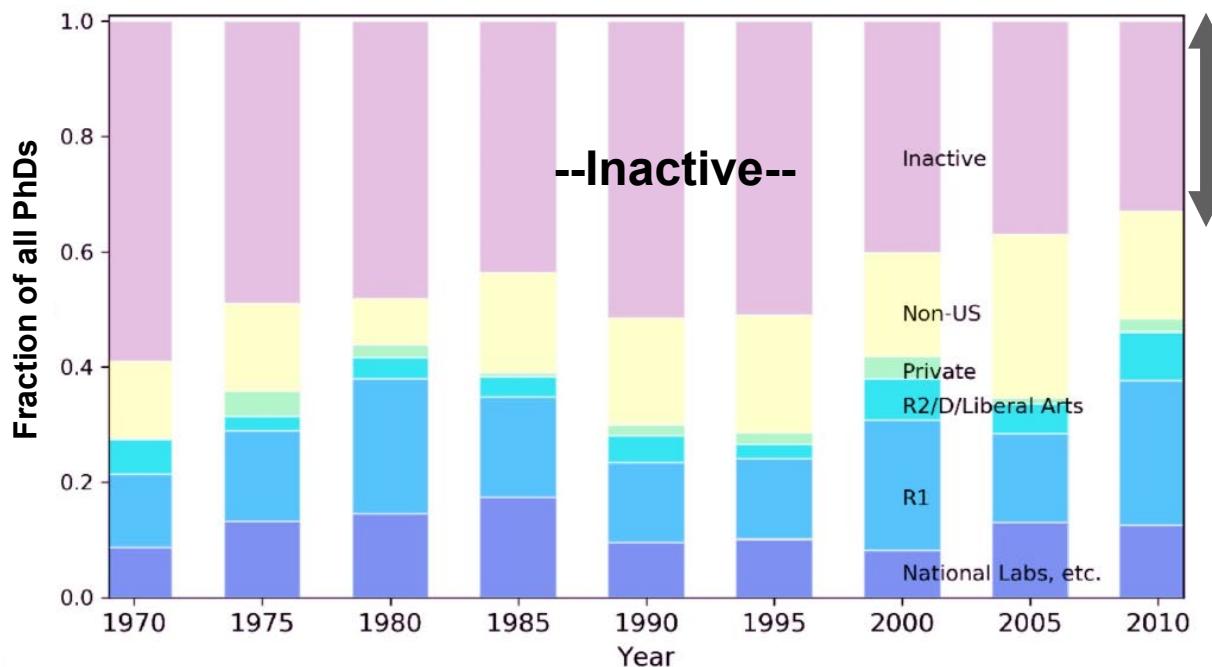
12-Year Cumulative Employment (Data 2000-2012)



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 now in excess of the number of careers available within the field.*" [Data for 2015]

Kamenetzky (2019): "*The overall availability of permanent positions in astronomy has increased in the past decade* [from ~300 per year in 1999] to ~380 per year in 2018." [Data from 2018] "This is years earlier, roughly coincident with the increase in new PhDs."

**CONCLUDE: NOT GLOOMY, NOT FLUSH.
TEMPERED OPTIMISM**

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

~1/3 Faculty

~1/3 Research Scientists

~1/3 Non Astronomy

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

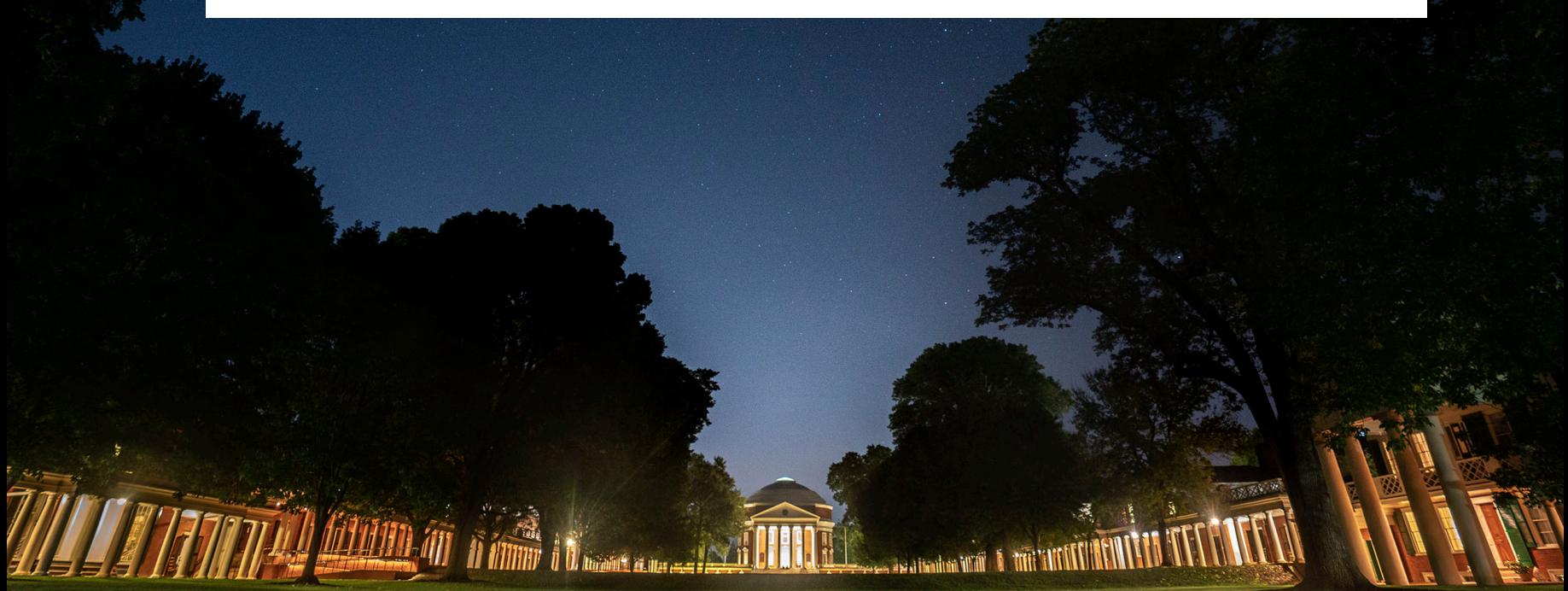
Part 2

Professional effort

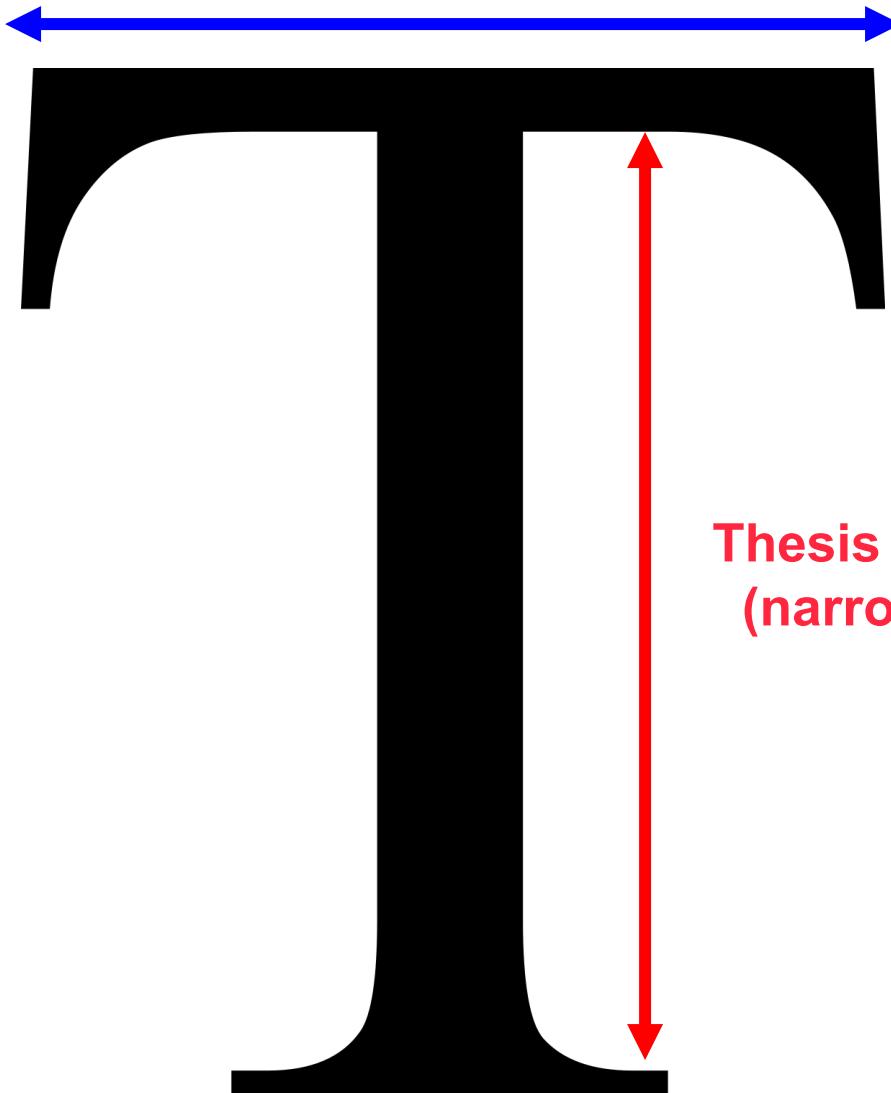
~95(?)%

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)**

Basics of many subfields (broad, shallow)
Coursework, colloquia, visitors, literature, etc



**BOTH BROAD AND NARROW ASPECTS
IMPORTANT TO JOB PROSPECTS**

Thesis research
(narrow, deep)

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 HCs
with a specific engagement
make in their solutions

**FROM POP-PSYCHOLOGY
TAKE WITH GRAIN OF SALT**

actual reconfiguration of neural

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
- Disciplinary activities, planning, meetings, advocacy
- National agency policy, planning, review

- **Consulting**



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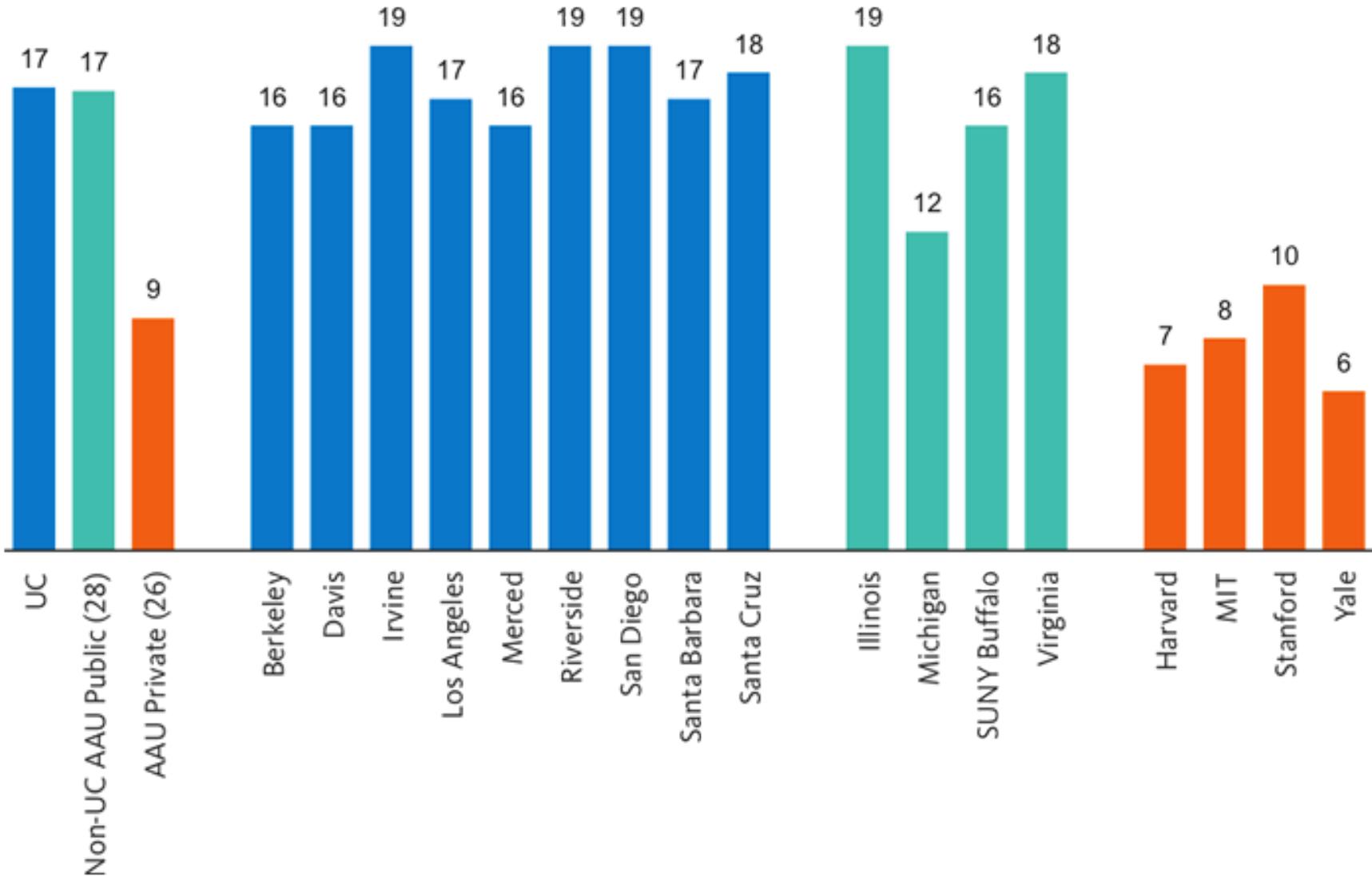
Almost no middle management

~90-200

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

= $10 \times S/F$ (in 3-credit classes)

Student/Faculty Ratios



~27:1

= Career averaged ratio of
total teaching time to
in-class 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



Ideas worth
spreading



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

A photograph of a TEDx event. A speaker stands on a stage with a red chair, facing a large audience seated in rows. The background features a large screen with the word "TED" in red and "Ideas" in white. The foreground is dominated by a large orange diagonal banner with the text "OPTIONAL TOPIC: 'HOW TO GIVE A BAD TALK'" in black, bold, sans-serif capital letters.

OPTIONAL TOPIC: "HOW TO GIVE A BAD TALK"

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

A photograph of a large lecture hall filled with students sitting in tiered rows, all using laptops. The room has a modern design with a glass wall in the background. An orange diagonal banner across the middle of the image contains the text.

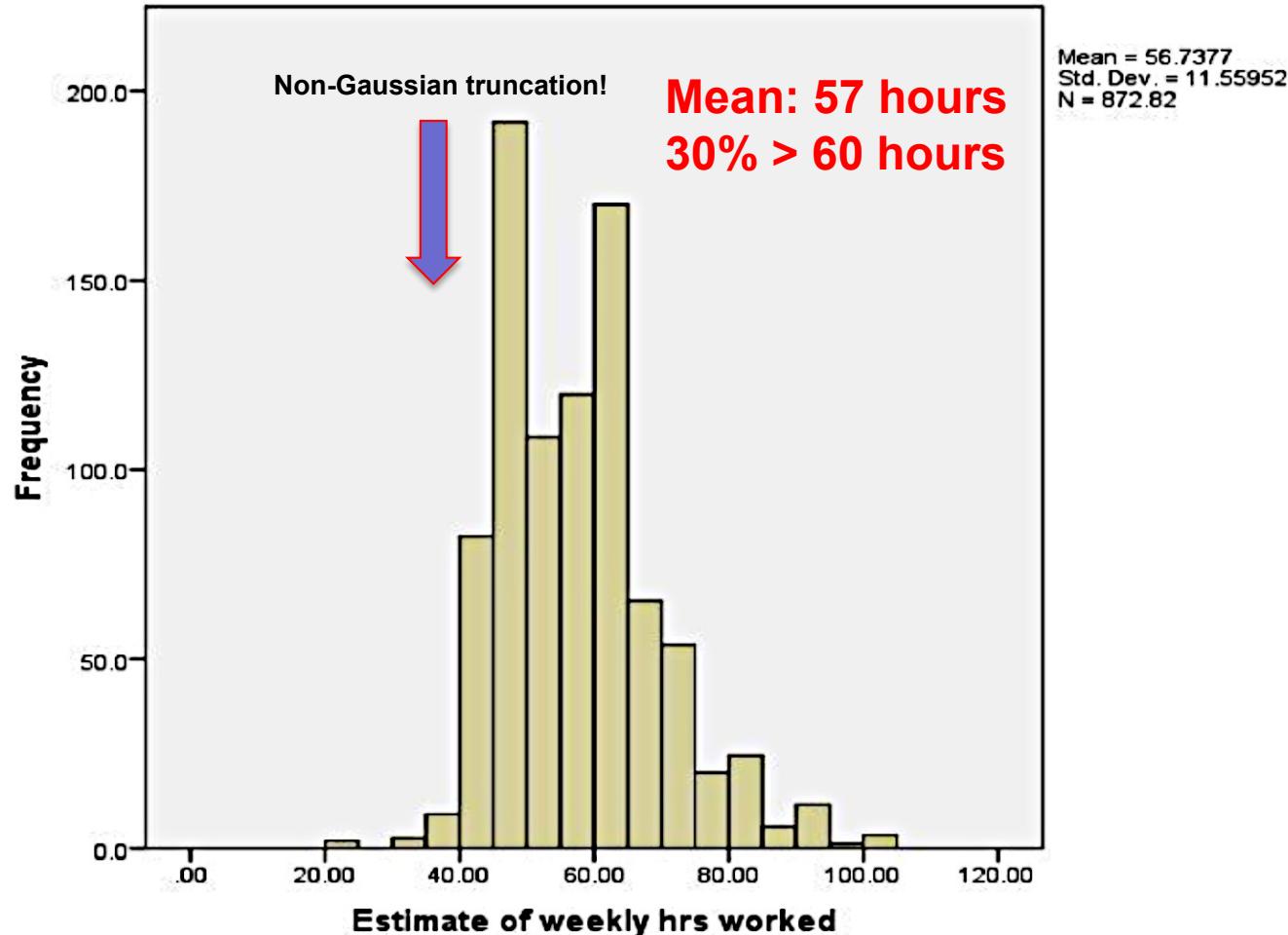
**MUST PLAN FOR HEAVY DEMANDS
OF TEACHING ON YOUR TIME**

~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.



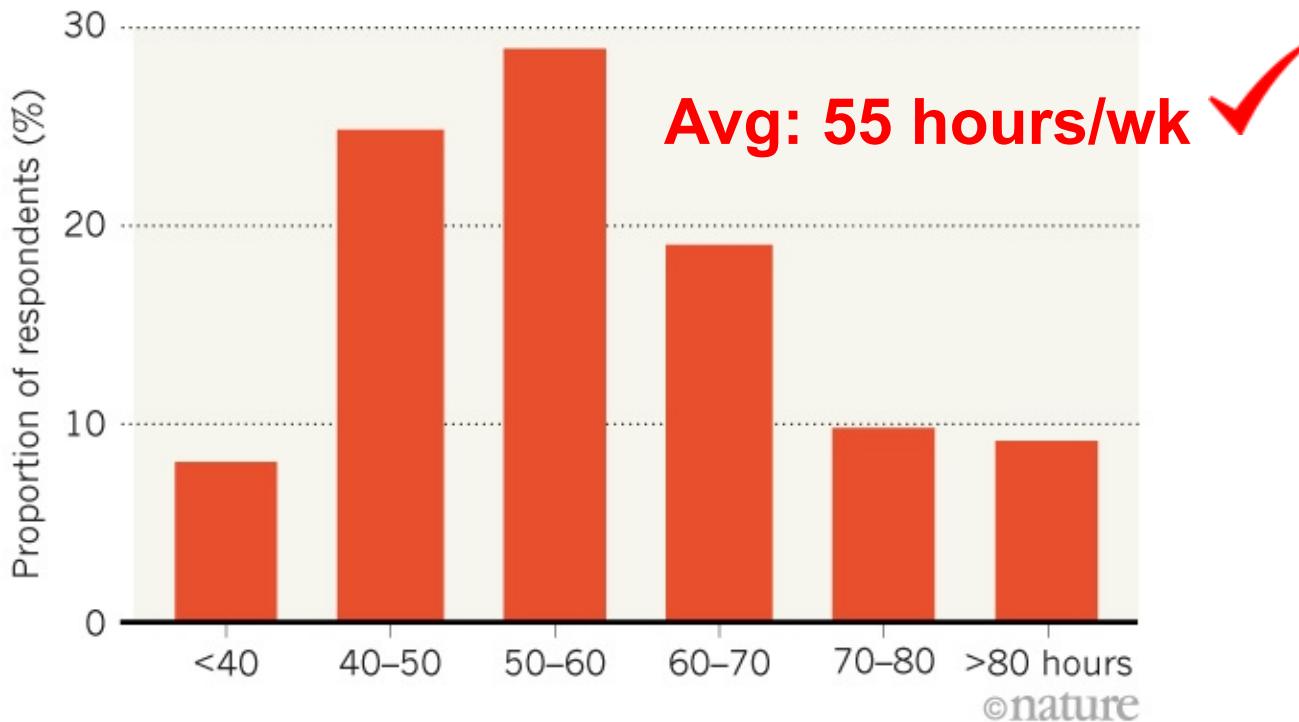
Scientist Survey: Hours Worked (Nature)

LONG HOURS

Some 38% of *Nature's* readers say they work more than 60 hours a week.

Poll question:

How many hours a week do you work on average? (12,869 responses)



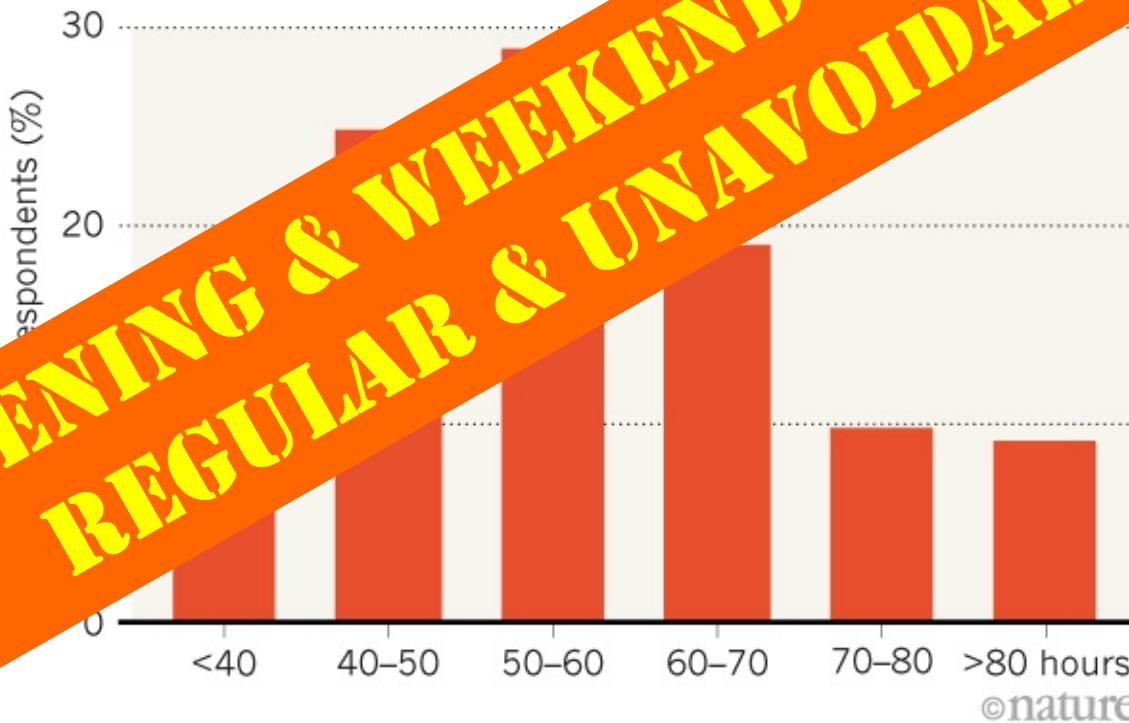
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©nature

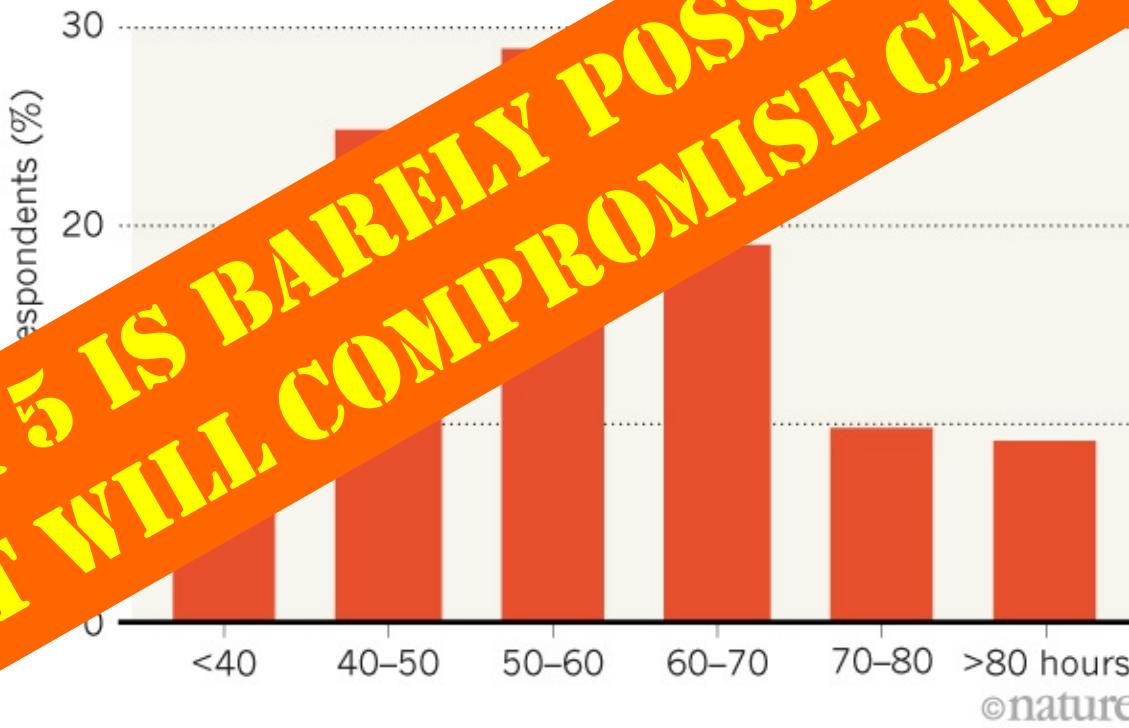
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©nature

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LONG HOURS

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Poll question:

How many hours a week do you work on average? (all responses)



©nature

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- Research
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- Service/Administration
 - Local, departmental, university, national, international: administration: operations, governance, policies, personnel, budgeting, hiring, promotions)
 - Refereeing manuscripts, proposal reviews
 - Disciplinary: committees, planning, meetings, advocacy
 - National agency: policy, planning, review
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**TIME MANAGEMENT
AN ESSENTIAL SKILL**

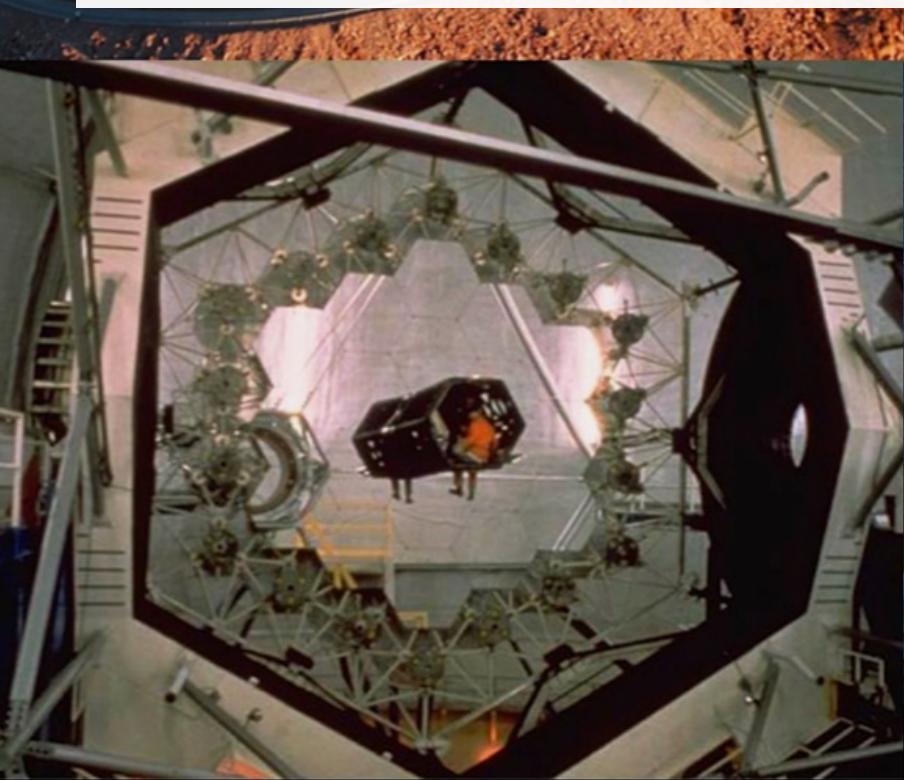
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 - Local, departmental, university administration: operations, governance, policies, personnel, hiring, tenure, promotion, promotions)
 - Refereeing manuscripts, proposal reviews
 - Disciplinary committees, planning, meetings, advocacy
 - National: 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

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

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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
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Abbott et al., "Multi-Messenger Observations of a
Binary Neutron Star Merger," ApJL, 848, L12, 2017

Abbott et all !



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, GRAVITÀ: 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 (See the end matter for the full list of authors.)

Received 2017 October 3; revised 2017 October 6; accepted 2017 October 6; published 2017 October 16

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 ~ 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}_{-6} 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 ~ 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 ~ 10 days. Following early non-detections, X-ray and radio emission were discovered at the transient's position ~ 9 and ~ 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).

* Any correspondence should be addressed to lvc.publications@ligo.org.



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B. P. Abbott¹, R. Abbott¹, T. D. Abbott², F. Acernese^{3,4}, K. Ackley^{5,6}, C. Adams⁷, T. Adams⁸, P. Addesso⁹, R. X. Adhikari¹, V. B. Adya¹⁰, C. Affeldt¹⁰, M. Afrough¹¹, B. Agarwal¹², M. Agathos¹³, K. Agatsuma¹⁴, N. Aggarwal¹⁵, O. D. Aguilar¹⁶, L. Aiello^{17,18}, A. Ain¹⁹, P. Ajith²⁰, B. Allen^{10,21,22}, G. Allen¹², A. Allocca^{23,24}, P. A. Altin²⁵, A. Amato²⁶, A. Ananyeva¹, S. B. Anderson¹, W. G. Anderson²¹, S. V. Angelova²⁷, S. Antier²⁸, S. Appert¹, K. Arai¹, M. C. Araya¹, J. S. Areeda²⁹, N. Arnaud^{28,30}, K. G. Arun³¹, S. Ascenzi^{32,33}, G. Ashton¹⁰, M. Ast³⁴, S. M. Aston⁷, P. Astone³⁵, D. V. Atallah³⁶, P. Aufmuth²², C. Aulbert¹⁰, K. AultONeal³⁷, C. Austin², A. Avila-Alvarez²⁹, S. Babak³⁸, P. Bacon³⁹, M. K. M. Bader¹⁴, S. Bae⁴⁰, P. T. Baker⁴¹, F. Baldaccini^{42,43}, G. Ballardin³⁰, S. W. Ballmer⁴⁴, S. Banagiri⁴⁵, J. C. Barayoga¹, S. E. Barclay⁴⁶, B. C. Barish¹, D. Barker⁴⁷, K. Barkett⁴⁸, F. Barone³⁴, B. Barr⁴⁶, L. Barsotti¹⁵, M. Barsuglia³⁹, D. Barta⁴⁹, S. D. Barthelmy⁵⁰, J. Bartlett⁴⁷, I. Bartos^{51,5}, R. Bassiri⁵², A. Basti^{23,24}, J. C. Batch⁴⁷, M. Bawaj^{53,43}, J. C. Bayley⁴⁶, M. Bazzan^{54,55}, B. Bécsy⁵⁶, C. Beer¹⁰, M. Bejger⁴⁷, I. Belahcene²⁸, A. S. Bell⁴⁶, B. K. Berger¹, G. Bergmann¹⁰, J. J. Bero⁵⁸, C. P. L. Berry⁵⁹, D. Bersanetti⁶⁰, A. Bertolini¹⁴, J. Betzwieser⁷, S. Bhagwat⁴⁴, R. Bhandare⁶¹, I. A. Bilenko⁶², G. Billingsley¹, C. R. Billman⁵, J. Birch⁷, R. Birney⁶³, O. Birnholz¹⁰, S. Biscans^{1,15}, S. Biscoveanu^{64,6}, A. Bishi²², M. Bitossi^{30,24}, C. Biwer⁴⁴, M. A. Bizouard²⁸, J. K. Blackburn¹, J. Blackman⁴⁸, C. D. Blair^{1,65}, D. G. Blair⁶⁵, R. M. Blair⁴⁷, S. Bloemen⁶⁶, O. Bock¹⁰, N. Bode¹⁰, M. Boer⁶⁷, G. Bogaert⁶⁷, A. Bohe³⁸, F. Bondu⁶⁸, E. Bonilla⁵², R. Bonnand⁸, B. A. Boom¹⁴, R. Bork¹, V. Boschi^{30,24}, S. Boso^{69,19}, K. Bossie⁷, Y. Bouffanais³⁹, A. Bozzo³⁰, C. Bradaschia²⁴, P. R. Brady²¹, M. Branchesi^{17,18}, J. E. Brau⁷⁰, T. Briant⁷¹, A. Brillet⁶⁷, M. Brinkmann¹⁰, V. Brisson²⁸, P. Brockill²¹, J. E. Broida⁷², A. F. Brooks¹.

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- 62 collaborations
 - (Can't fit in AstroPH author display)
- 3611 authors
- Author list is 10 pages long
 - (Normal ApJL total length is 4 pgs)
- 953 institutional affiliations
- Acknowledgements take 6 pgs
- 4 authors are already dead

P. Gruning²⁸, G. M. Guidi^{121,122}, X. Guo⁸², A. Gupta⁶⁴, M. K. Gupta¹⁰⁵, K. E. Gushwa¹, E. K. Gustafson¹, R. Gustafson¹¹⁸, O. Halim^{18,17}, B. R. Hall⁶⁹, E. D. Hall¹⁵, E. Z. Hamilton³⁶, G. Hammond⁴⁶, M. Haney¹²³, M. M. Hanke¹⁰, J. Hanks⁴⁷, C. Hanna⁶⁴, M. D. Hannam³⁶, O. A. Hannuksela⁹³, J. Hanson⁷, T. Hardwick², J. Harms^{17,18}, G. M. Harry¹²⁴, I. W. Harry³⁸, M. J. Hart⁴⁶, C.-J. Haster⁹⁰, K. Haughian⁴⁶, J. Healy⁵⁸, A. Heidmann⁷¹, M. C. Heintze⁷, H. Heitmann⁶⁷, P. Hello²⁸, G. Hemming³⁰, M. Hendry⁴⁶, I. S. Heng⁴⁶, J. Hennig⁴⁶, A. W. Heptonstall¹, M. Heurs^{10,22}, S. Hild⁴⁶, T. Hinderer⁶⁶, D. Hoak³⁰, D. Hofman²⁶, K. Holt⁷, D. E. Holz⁹¹, P. Hopkins³⁶, C. Horst²¹, J. Hough⁴⁶, E. A. Houston⁴⁶, E. J. Howell⁵⁵, A. Hreibi⁶⁷, Y. M. Hu¹⁰, E. A. Huerta¹², D. Huet²⁸, B. Hughay³⁷, S. Husa¹⁰², S. Huttner⁴⁶, T. Huynh-Dinh⁷, N. Indik¹⁰, R. Inta⁸³, G. Intini^{97,35}, H. N. Isa⁴⁶, J.-M. Isac⁷¹, M. Isi¹, B. R. Iyer²⁰, K. Izumi⁴⁷, T. Jacqmin⁷¹, K. Jani⁷⁷, P. Jaradowski¹²⁵, S. Jawahar⁶³, F. Jiménez-Forteza¹⁰², W. W. Johnson², D. I. Jones¹²⁶, R. Jones⁴⁶, R. J. G. Jonker¹⁴, L. Ju⁶⁵, J. Junker¹⁰, C. V. Kalaghatgi³⁶, V. Kalogera⁸⁹, B. Kamai¹, S. Kandhasamy⁷, G. Kang⁴⁰, J. B. Kanner¹, S. J. Kapadia²¹, S. Karki⁷⁰, J.

Multimessenger search for sources of gravitational waves and high-energy neutrinos: Initial results for LIGO-Virgo and IceCube

- M. G. Aartsen,^{2,*} M. Ackermann,^{45,*} J. Adams,^{15,*} J. A. Aguilar,^{23,*} M. Ahlers,^{28,*} M. Ahrens,^{36,*} D. Altmann,^{22,*} T. Anderson,^{42,*} C. Arguelles,^{28,*} T. C. Arlen,^{42,*} J. Auffenberg,^{1,*} X. Bai,^{34,*} S. W. Barwick,^{25,*} V. Baum,^{29,*} J. J. Beatty,^{17,18,*} J. Becker Tjus,^{10,*} K.-H. Becker,^{44,*} S. BenZvi,^{28,*} P. Berghaus,^{45,*} D. Berley,^{16,*} E. Bernardini,^{45,*} A. Bernhard,^{31,*} D. Z. Besson,^{26,*} G. Binder,^{8,7,*} D. Bindig,^{44,*} M. Bissok,^{1,*} E. Blaufuss,^{16,*} J. Blumenthal,^{1,*} D. J. Boersma,^{43,*} C. Bohm,^{36,*} F. Bos,^{10,*} D. Böse,^{38,*} S. Böser,^{11,*} O. Botner,^{43,*} L. Brayeur,^{13,*} H.-P. Bretz,^{45,*} A. M. Brown,^{15,*} J. Casey,^{5,*} M. Casier,^{13,*} D. Chirkov,^{28,*} A. Christov,^{23,*} B. Christy,^{16,*} K. Clark,^{39,*} L. Classen,^{22,*} F. Clevermann,^{20,*} S. Coenders,^{31,*} D. F. Cowen,^{42,41,*} A. H. Cruz Silva,^{45,*} M. Danninger,^{36,*} J. Daughhetee,^{5,*} J. C. Davis,^{17,*} M. Day,^{28,*} J. P. A. M. de André,^{42,*} C. De Clercq,^{13,*} S. De Ridder,^{24,*} P. Desiati,^{28,*} K. D. de Vries,^{29,*} M. de With,^{9,*} T. De Young,^{42,*} J. C. Díaz-Vélez,^{28,*} M. Dunkman,^{42,*} R. Eagan,^{42,*} B. Eberhardt,^{29,*} B. Eichler,^{29,*} J. Eisch,^{28,*} S. Euler,^{43,*} P. A. Evenson,^{32,*} O. Fadiran,^{28,*} A. R. Fazely,^{6,*} A. Fedynitch,^{10,*} J. Feintzeig,^{10,*} T. Feusels,^{24,*} K. Filimonov,^{7,*} C. Finley,^{36,*} T. Fischer-Wasels,^{44,*} S. Flis,^{36,*} A. Franckowiak,^{1,*} T. Fuchs,^{20,*} T. K. Gaisser,^{32,*} J. Gallagher,^{27,*} L. Gerhardt,^{8,7,*} D. Gier,^{1,*} L. Gladstone,^{1,*} A. Goldschmidt,^{8,*} G. Golup,^{13,*} J. G. Gonzalez,^{32,*} J. A. Goodman,^{16,*} D. Góra,^{45,*} D. Goss,^{1,*} P. Gretskov,^{1,*} J. C. Groh,^{42,*} A. Groß,^{31,*} C. Ha,^{8,7,*} C. Haack,^{1,*} A. Haj Ismail,^{1,*} F. Halzen,^{28,*} K. Hanson,^{12,*} D. Hebecker,^{11,*} D. Heereman,^{12,*} D. Heinrich,^{1,*} K. Hickford,^{15,*} G. C. Hill,^{2,*} K. D. Hoffman,^{16,*} R. Hoffmann,^{44,*} A. Huelsnitz,^{16,*} P. O. Huith,^{36,*} K. Hultqvist,^{36,*} S. Hussain,^{32,*} K. Jagielinski,^{1,*} G. S. Japaridze,^{4,*} K. Jero,^{28,*} O. Jlelati,^{24,*} M. Karle,^{28,*} M. Kauer,^{28,*} J. L. Kelley,^{28,*} A. Kheirandish,^{1,*} G. Kohnen,^{30,*} H. Kolanoski,^{9,*} A. Koob,^{1,*} L. Köpke,^{1,*} A. Kriesten,^{1,*} K. Krings,^{1,*} G. Kroll,^{29,*} M. Kutschera,^{1,*} D. T. Larsen,^{28,*} M. J. Larson,^{19,*} M. Lesiak,^{1,*} J. Lohmann,^{1,*} J. Madsen,^{35,*} G. Maggi,^{13,*} R. Maruyama,^{1,*} A. Meli,^{24,*} T. Meures,^{12,*} S. Mirelman,^{1,*} T. Montaruli,^{23,*} R. Morse,^{28,*} A. Obertacke,^{44,*} S. Ö. Penek,^{1,*} P. B. Price,^{28,*} I. Rees,^{28,*} F. Scherian,^{20,*} T. Schmidt,^{16,*} M. Schmitz,^{20,*} F. Scherian,^{20,*} T. Schultheis,^{11,*} O. Schulz,^{31,*} D. Seckel,^{32,*} S. Sehgal,^{21,*} M. W. E. Smith,^{42,*} D. Soldin,^{44,*} G. M. Spiczak,^{35,*} A. Stanisha,^{42,*} A. Stasik,^{11,*} T. Stezelberger,^{8,*} R. G. Stokstad,^{8,*} N. L. Strotzmann,^{11,*} G. W. Sullivan,^{16,*} H. Taavola,^{43,*} I. Taboada,^{5,*} J. Terliuk,^{45,*} G. Tešić,^{42,*} S. Tilav,^{32,*} P. A. Toale,^{40,*} M. N. Tobin,^{28,*} T. Voge,^{11,*} M. Vraeghe,^{24,*} C. Walck,^{36,*} M. Wallraff,^{1,*} Ch. Weaver,^{28,*} M. Wellons,^{28,*} B. J. Whelan,^{2,*} N. Whitehorn,^{28,*} C. Wichary,^{1,*} K. Wiebe,^{29,*} C. H. Wiebusch,^{1,*} J. Wissing,^{16,*} M. Wolf,^{36,*} T. R. Wood,^{21,*} K. Woschnagg,^{7,*} D. L. Xu,^{40,*} X. W. Xu,^{6,*} J. P. Yanecz,^{45,*} T. Yoshida,^{14,*} P. Zarzhitsky,^{40,*} J. Ziemann,^{20,*} S. Zierke,^{1,*} M. Zoll,^{36,*} J. Aasi,^{46,*} B. P. Abbott,^{46,*} T. Abbott,^{47,*} M. R. Abernathy,^{46,*} F. Acernese,^{48,49,*} K. Ackley,^{50,*} C. Adams,^{51,*} T. Adams,^{32,*} A. Adulesso,^{53,*} R. X. Adhikari,^{46,*} C. Affeldt,^{54,*} M. Agathos,^{55,*} N. Aggarwal,^{56,*} O. D. Aguiar,^{57,*} P. Ajith,^{58,*} A. Alemic,^{59,*} B. Allen,^{54,60,61,*} A. Allocata,^{62,63,*} D. Amariutei,^{50,*} M. Andersen,^{64,*} R. A. Anderson,^{46,*} S. B. Anderson,^{46,*} W. G. Anderson,^{60,*} K. Arai,^{46,*} M. C. Araya,^{46,*} C. Arceneaux,^{65,*} J. S. Areeda,^{66,*} S. Ast,^{61,*} S. M. Aston,^{51,*} P. Astone,^{67,*} P. Aufmuth,^{61,*} H. Augustus,^{68,*} C. Aulbert,^{54,*} B. E. Aylott,^{68,*} S. Babak,^{69,*} P. T. Baker,^{70,*} G. Ballardin,^{71,*} S. W. Ballmer,^{59,*} J. C. Barayoga,^{46,*} M. Barbet,^{50,*} B. C. Barish,^{46,*} D. Barker,^{72,*} F. Barone,^{48,49,*} B. Barr,^{73,*} L. Barsotti,^{56,*} M. Barsuglia,^{74,*} M. A. Barton,^{72,*} I. Bartos,^{75,*} R. Bassiri,^{64,*} A. Basti,^{76,63,*} J. C. Batch,^{72,*} J. Bauchrowitz,^{54,*} Th. S. Bauer,^{55,*} C. Baune,^{54,*} V. Bavigadda,^{71,*} B. Behnke,^{69,*} M. Beijer,^{77,*} M. G. Beker,^{55,*} C. Belczynski,^{78,*} A. S. Bell,^{73,*} C. Bell,^{73,*} G. Bergmann,^{54,*} D. Bersanetti,^{79,80,*} A. Bertolini,^{55,*} J. Betzwieser,^{51,*} I. A. Bilenko,^{81,*} G. Billingsley,^{46,*} J. Birch,^{51,*} S. Biscans,^{56,*} M. Bitossi,^{63,*} C. Biwer,^{59,*} M. A. Bizouard,^{82,*} E. Black,^{46,*} J. K. Blackburn,^{46,*} L. Blackburn,^{83,*} D. Blair,^{84,*} S. Bloemen,^{55,85,*} O. Bock,^{54,*} T. P. Bodiya,^{56,*} M. Boer,^{86,*}

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PARTICIPATION & MANAGEMENT**

Multimessenger search for sources of gravitational waves and high-energy neutrinos: Initial results for LIGO-Virgo and IceCube

- M. G. Aartsen,^{2,*} M. Ackermann,^{45,*} J. Adams,^{15,*} J. A. Aguilar,^{23,*} M. Ahlers,^{28,*} M. Ahrens,^{36,*} D. Altmann,^{22,*} T. Anderson,^{42,*} C. Arguelles,^{28,*} T. C. Arlen,^{42,*} J. Aufenberg,^{1,*} X. Bai,^{34,*} S. W. Barwick,^{25,*} V. Baum,^{29,*} J. J. Beatty,^{17,18,*} J. Becker Tjus,^{10,*} K.-H. Becker,^{44,*} S. BenZvi,^{28,*} P. Berghaus,^{45,*} D. Berley,^{16,*} E. Bernardini,^{45,*} A. Bernhard,^{31,*} D. Z. Besson,^{26,*} G. Binder,^{8,7,*} D. Bindig,^{44,*} M. Bissok,^{1,*} E. Blaufuss,^{16,*} J. Blumenthal,^{1,*} D. J. Boersma,^{43,*} C. Bohm,^{36,*} F. Bos,^{10,*} D. Böse,^{38,*} S. Böser,^{11,*} O. Botner,^{43,*} L. Brayeur,^{13,*} H.-P. Bretz,^{45,*} A. M. Brown,^{15,*} J. Casey,^{5,*} M. Casier,^{13,*} D. Chirkov,^{28,*} A. Christov,^{23,*} B. Christy,^{16,*} K. Clark,^{39,*} L. Classen,^{22,*} F. Clevermann,^{20,*} S. Coenders,^{31,*} D. F. Cowen,^{42,41,*} A. H. Cruz Silva,^{45,*} M. Danninger,^{36,*} J. Daughhetee,^{5,*} J. C. Davis,^{17,*} M. Day,^{28,*} J. P. A. M. de André,^{42,*} C. De Clercq,^{13,*} S. De Ridder,^{24,*} P. Desiati,^{28,*} K. D. de Vries,^{29,*} M. de With,^{9,*} T. De Young,^{42,*} J. C. Díaz-Vélez,^{28,*} M. Dunkman,^{42,*} R. Eagan,^{42,*} B. Eberhardt,^{29,*} B. Eichler,^{29,*} J. Eisch,^{28,*} S. Euler,^{43,*} P. A. Evenson,^{32,*} O. Fadiran,^{28,*} A. R. Fazely,^{6,*} A. Fedynitch,^{10,*} J. Feintzeig,^{28,*} T. Feusels,^{24,*} K. Filimonov,^{7,*} C. Finley,^{36,*} T. Fischer-Wasels,^{44,*} S. Flis,^{36,*} A. Franckowiak,^{28,*} T. Fuchs,^{20,*} T. K. Gaisser,^{32,*} J. Gallagher,^{27,*} L. Gerhardt,^{8,7,*} D. Gier,^{1,*} L. Gladstone,^{28,*} A. Goldschmidt,^{8,*} G. Golup,^{13,*} J. G. Gonzalez,^{32,*} J. A. Goodman,^{16,*} D. Góra,^{45,*} D. Goss,^{28,*} P. Gretskov,^{1,*} J. C. Groh,^{42,*} A. Groß,^{31,*} C. Ha,^{8,7,*} C. Haack,^{1,*} A. Haj Ismail,^{28,*} F. Halzen,^{28,*} K. Hanson,^{12,*} D. Hebecker,^{11,*} D. Heereman,^{12,*} D. Heinrich,^{1,*} K. Hickford,^{15,*} G. C. Hill,^{2,*} K. D. Hoffman,^{16,*} R. Hoffmann,^{44,*} A. Huelsnitz,^{16,*} P. O. Hulth,^{36,*} K. Hultqvist,^{36,*} S. Hussain,^{32,*} K. Jagielinski,^{1,*} G. S. Japaridze,^{4,*} K. Jero,^{28,*} O. Jlelati,^{24,*} M. Karle,^{28,*} M. Kauer,^{28,*} J. L. Kelley,^{28,*} A. Kheirandish,^{28,*} G. Kohnen,^{30,*} H. Kolanoski,^{9,*} A. Koob,^{1,*} L. Köpke,^{28,*} A. Kriesten,^{1,*} K. Krings,^{1,*} G. Kroll,^{29,*} M. Kutschera,^{28,*} D. T. Larsen,^{28,*} M. J. Larson,^{19,*} M. Lesiak,^{28,*} J. Madsen,^{35,*} G. Maggi,^{13,*} R. Maruyama,^{28,*} A. Meli,^{24,*} T. Meures,^{12,*} S. Mirelman,^{28,*} T. Montaruli,^{23,*} R. Morse,^{28,*} A. Obertacke,^{44,*} S. Ö. Penek,^{1,*} P. B. Price,^{28,*} I. Rees,^{28,*} F. Scherian,^{20,*} T. Schmidt,^{16,*} M. Schmitz,^{20,*} F. Scherian,^{20,*} T. Schultheis,^{11,*} O. Schulz,^{31,*} D. Seckel,^{32,*} S. Sehgal,^{28,*} J. S. Sander,^{28,*} A. Stanisha,^{42,*} A. Stasik,^{11,*} T. Stezelberger,^{8,*} R. G. Stokstad,^{8,*} N. L. Strotzmann,^{21,*} A. Strotzmann,^{21,*} A. Strotzmann,^{21,*} A. Strotzmann,^{21,*} A. Strotzmann,^{21,*} A. Strotzmann,^{21,*} A. Terliuk,^{45,*} G. Tešić,^{42,*} S. Tilav,^{32,*} P. A. Toale,^{40,*} M. N. Tobin,^{28,*} M. Usluer,^{11,*} S. Vallecorsa,^{23,*} N. van Eijndhoven,^{13,*} J. Vandembroucke,^{28,*} T. Voge,^{11,*} M. Vraeghe,^{24,*} C. Walck,^{36,*} M. Wallraff,^{1,*} Ch. Weaver,^{28,*} M. Wellons,^{28,*} B. J. Whelan,^{2,*} N. Whitehorn,^{28,*} C. Wichary,^{1,*} K. Wiebe,^{29,*} C. H. Wiebusch,^{28,*} M. Wissing,^{16,*} M. Wolf,^{36,*} T. R. Wood,^{21,*} K. Woschnagg,^{7,*} D. L. Xu,^{40,*} X. W. Xu,^{6,*} J. P. Yanecz,^{45,*} P. Aufmuth,^{61,*} H. Augustus,^{68,*} C. Aulbert,^{54,*} B. E. Aylott,^{68,*} S. Babak,^{69,*} P. T. Baker,^{70,*} G. Ballardin,^{71,*} S. W. Ballmer,^{59,*} J. C. Barayoga,^{46,*} M. Barber,^{50,*} B. C. Barish,^{46,*} D. Barker,^{72,*} F. Barone,^{48,49,*} B. Barr,^{73,*} L. Barsotti,^{56,*} M. Barsuglia,^{74,*} M. A. Barton,^{72,*} I. Bartos,^{75,*} R. Bassiri,^{64,*} A. Basti,^{76,63,*} J. C. Batch,^{72,*} J. Bauchrowitz,^{54,*} Th. S. Bauer,^{55,*} C. Baune,^{54,*} V. Bavigadda,^{71,*} B. Behnke,^{69,*} M. Beijer,^{77,*} M. G. Beker,^{55,*} C. Belczynski,^{78,*} A. S. Bell,^{73,*} C. Bell,^{73,*} G. Bergmann,^{54,*} D. Bersanetti,^{79,80,*} A. Bertolini,^{55,*} J. Betzwieser,^{51,*} I. A. Bilenko,^{81,*} G. Billingsley,^{46,*} J. Birch,^{51,*} S. Biscans,^{56,*} M. Bitossi,^{63,*} C. Biwer,^{59,*} M. A. Bizouard,^{82,*} E. Black,^{46,*} J. K. Blackburn,^{46,*} L. Blackburn,^{83,*} D. Blair,^{84,*} S. Bloemen,^{55,85,*} O. Bock,^{54,*} T. P. Bodiya,^{56,*} M. Boer,^{86,*}

OPTIONAL TOPIC: "NAVIGATING GROUP SCIENCE"



A dark blue night sky filled with numerous small white stars of varying brightness. In the lower portion of the image, the Earth's horizon is visible, showing a bright, glowing blue line where the atmosphere meets space. The rest of the planet is in deep shadow, appearing dark blue.

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