

# *Numbers You Should Know*

## *Part 1*

ASTR 8500

Spring 2020

Robert W. O'Connell

# Sources?

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



# *A National Perspective on Astronomy*



We're #3!

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

#1 Health & Medicine

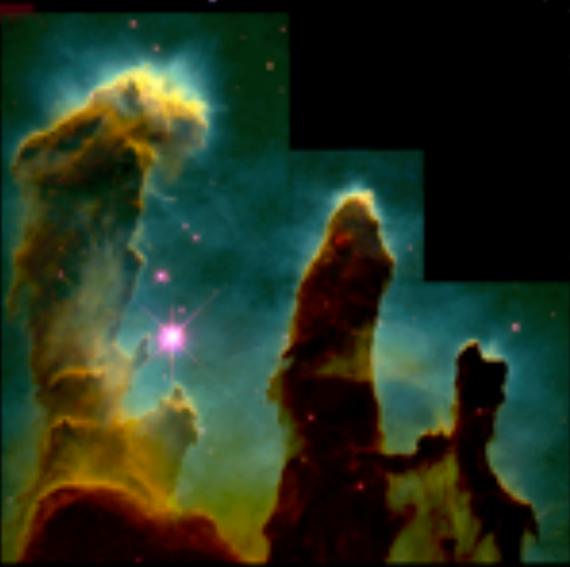
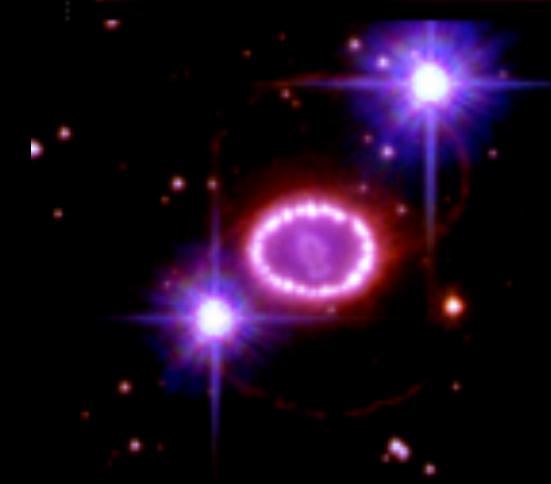
#2 Environment

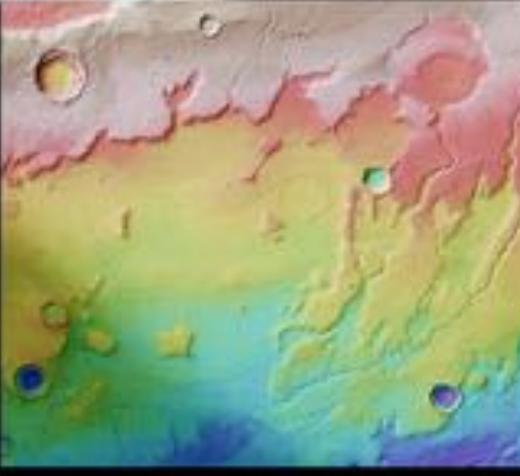
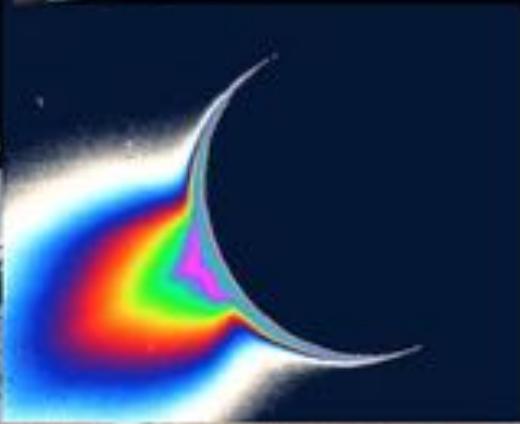
#3 Astronomy & Space

# 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

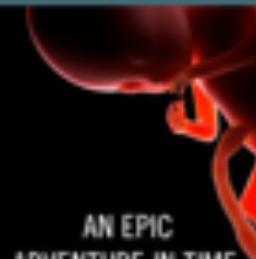
Presented by FOX Sun 9/8c and National Geographic Mon 10/9c

Blog Clips Live Event

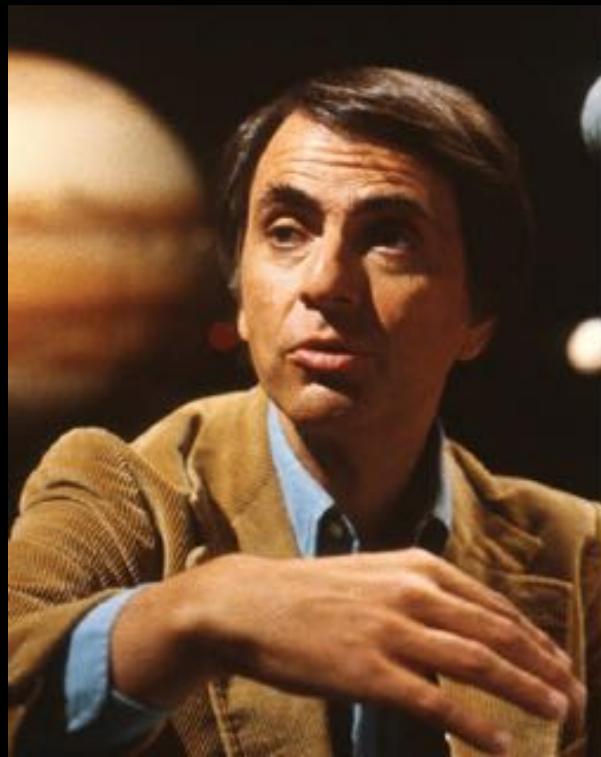
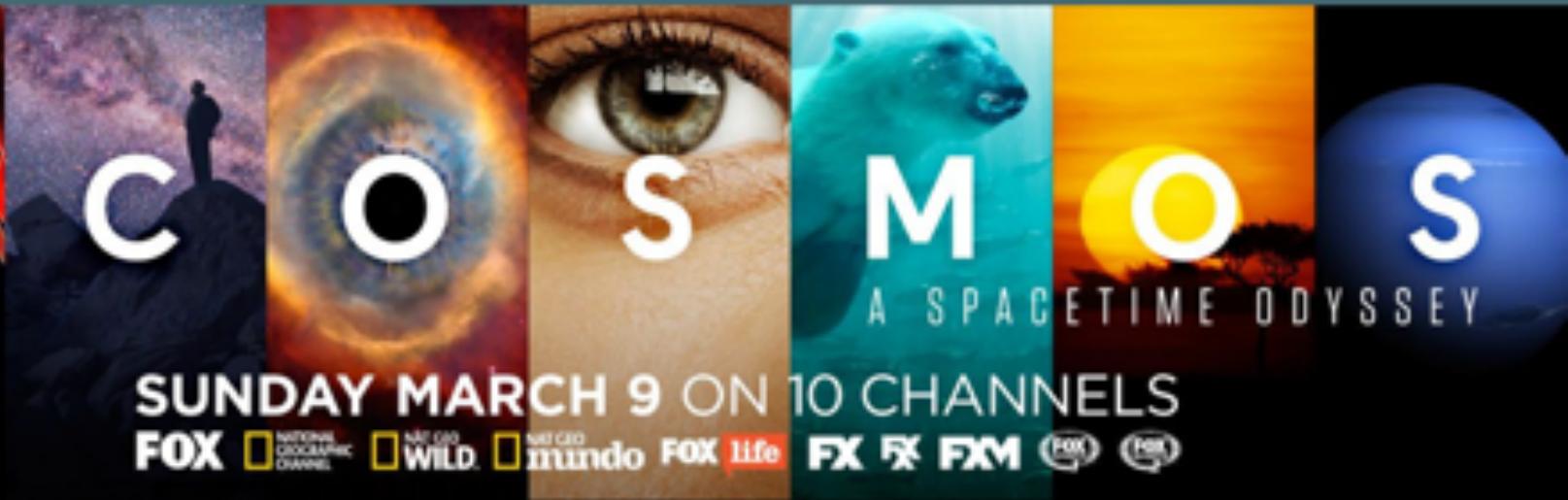


Samsung GALAXY

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.

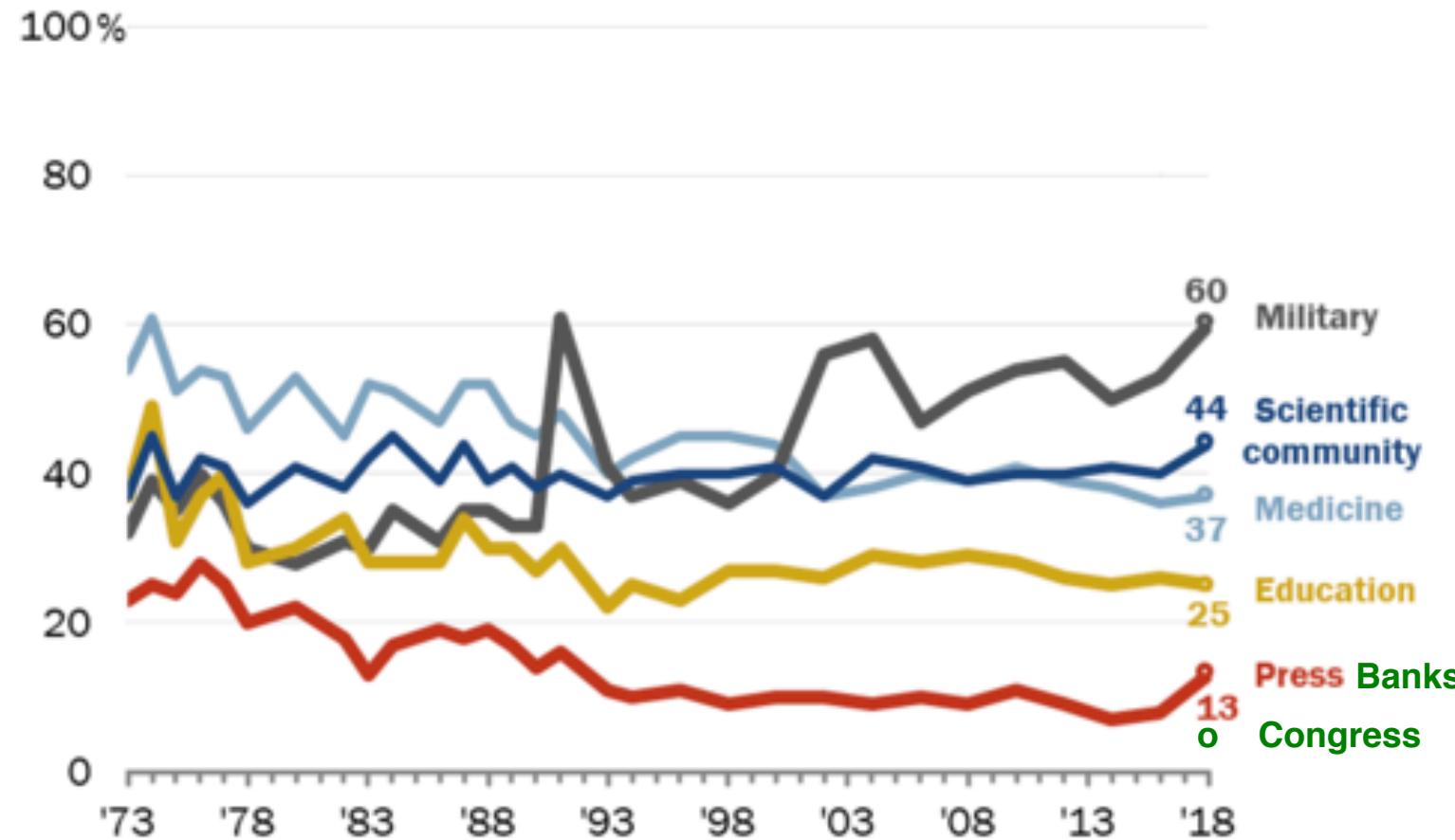
That's nearly twice the number of people that watched the Super Bowl last year. It's [almost 30 percent more Americans](#) than participated in the presidential election last year.



"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



\$425,000

= National budget for astronomy  
per astronomer

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

1974



1990



...Mostly in the form of *shared observing facilities*

1992



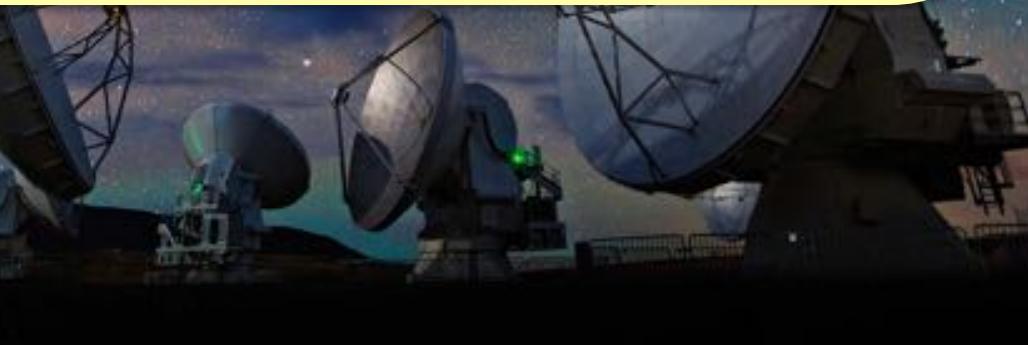
2011





Astronomy is ~uniquely dependent on  
large, shared experimental facilities

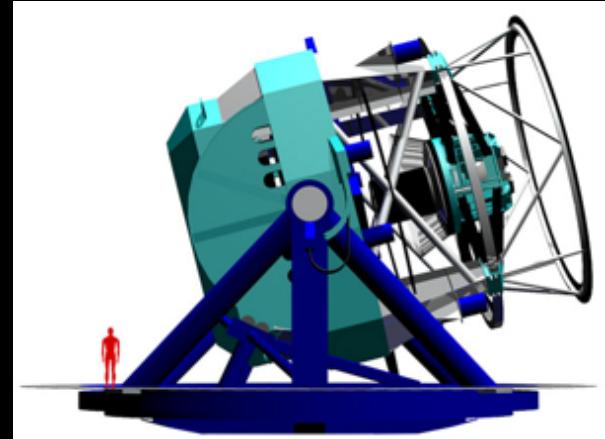
Astronomical facilities have long  
productive lifetimes; a blessing & a curse



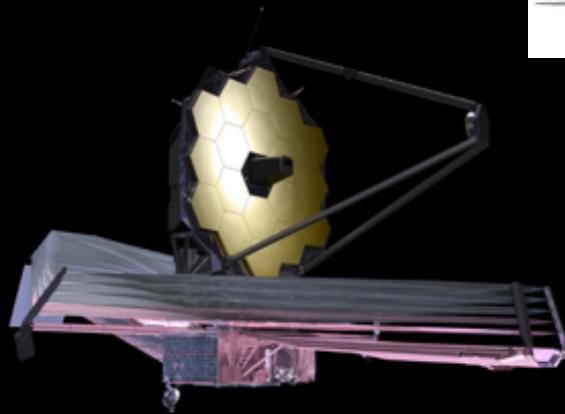
# Promise of the Next Decade



ALMA



LSST



JWST



GMT



WFIRST



# *The Job Market*

# 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, NOAO, GSFC, STScI, USNO). Independent contractors (e.g. 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," computing/big data, aerospace, sensors, optics & imaging, defense, finance...

# 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)

2/3

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

~1/3 Faculty

~1/3 Research Scientists

~1/3 Non Astronomy

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

~1/3 Faculty

~1/3 Research Scientists

~1/3 Non Astronomy

65%

(Perley 2019)

# How many jobs?

# HAPPY 2020

Here's a quick selection of notable accomplishments in 2019:

- 13 million article downloads from our research journals — the *Astronomical Journal*, *Astrophysical Journal*, *Astrophysical Journal Letters*, *Astrophysical Journal Supplements*, and *Research Notes of the AAS*
- 2,550 unique presenters at AAS meetings
- 1,150 talks at AAS meetings
- 1,600 posters and iPosters at AAS meetings
- 1,000 new AAS members and affiliates engaged in the astronomical sciences

## SKY & TELESCOPE

The AAS acquired *Sky & Telescope* magazine, [SkyandTelescope.com](#), S&T's astronomy-themed tours, and the company's line of star atlases, celestial globes, and other products.

## THE PLANETARY SCIENCE JOURNAL

The AAS and its Division for Planetary Sciences launched a new gold open access journal for the publication of planetary science research.

AAS MEMBERS AND COUNTING

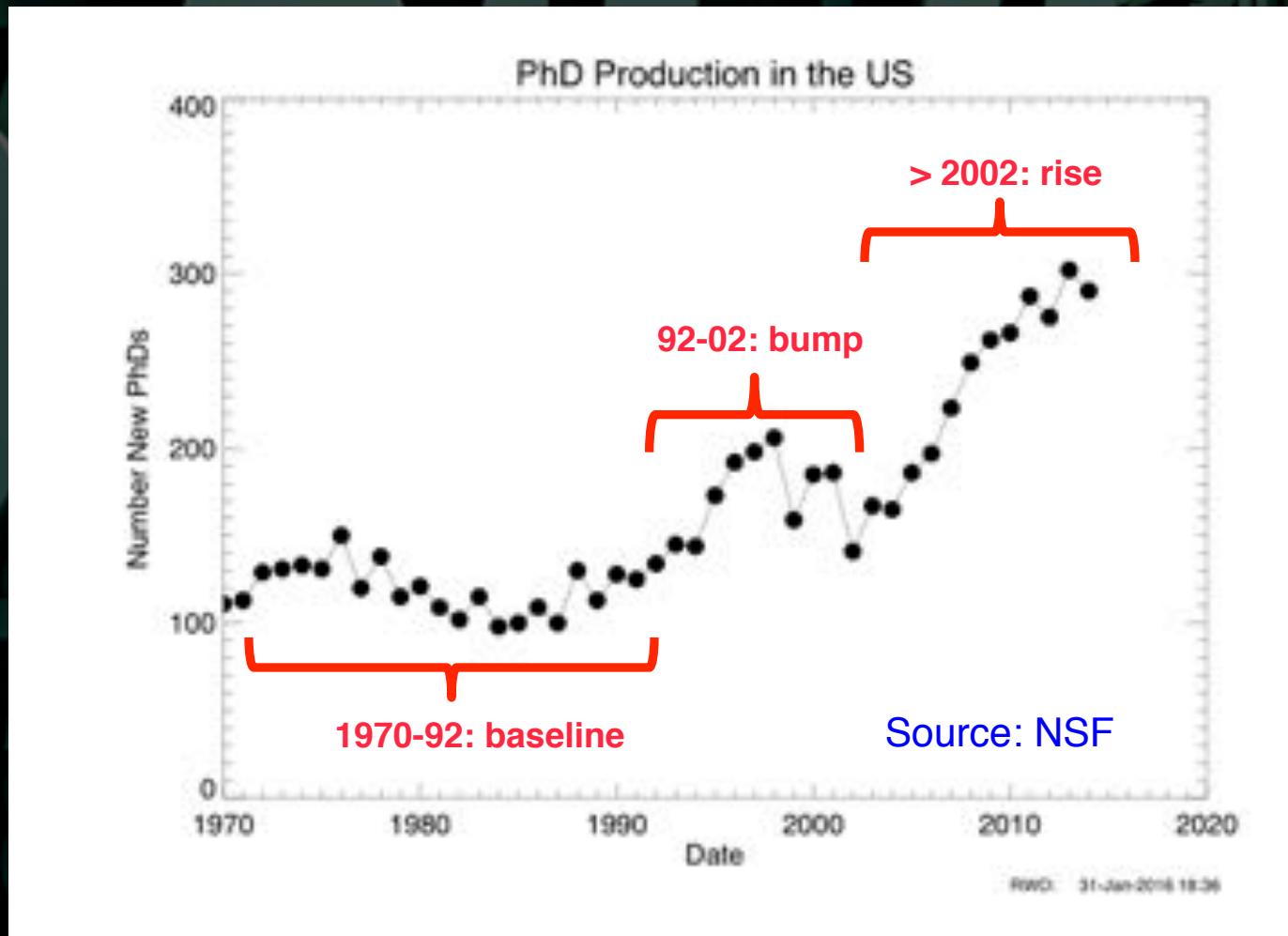
8,902

# How many jobs?

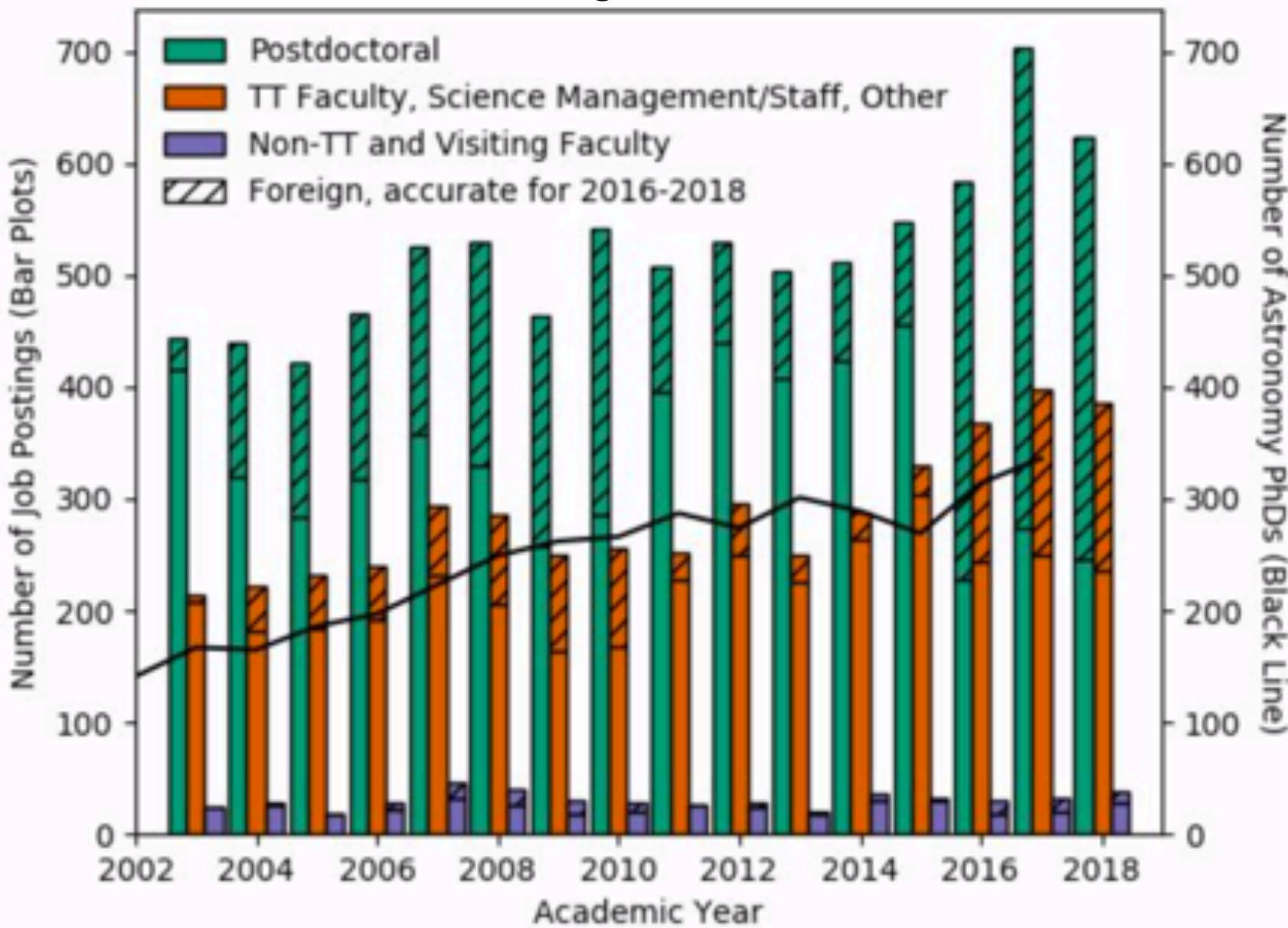
~8500

= Membership of AAS + Nonmembers  
- Non-grad degrees

# Production of New Astronomy PhD's



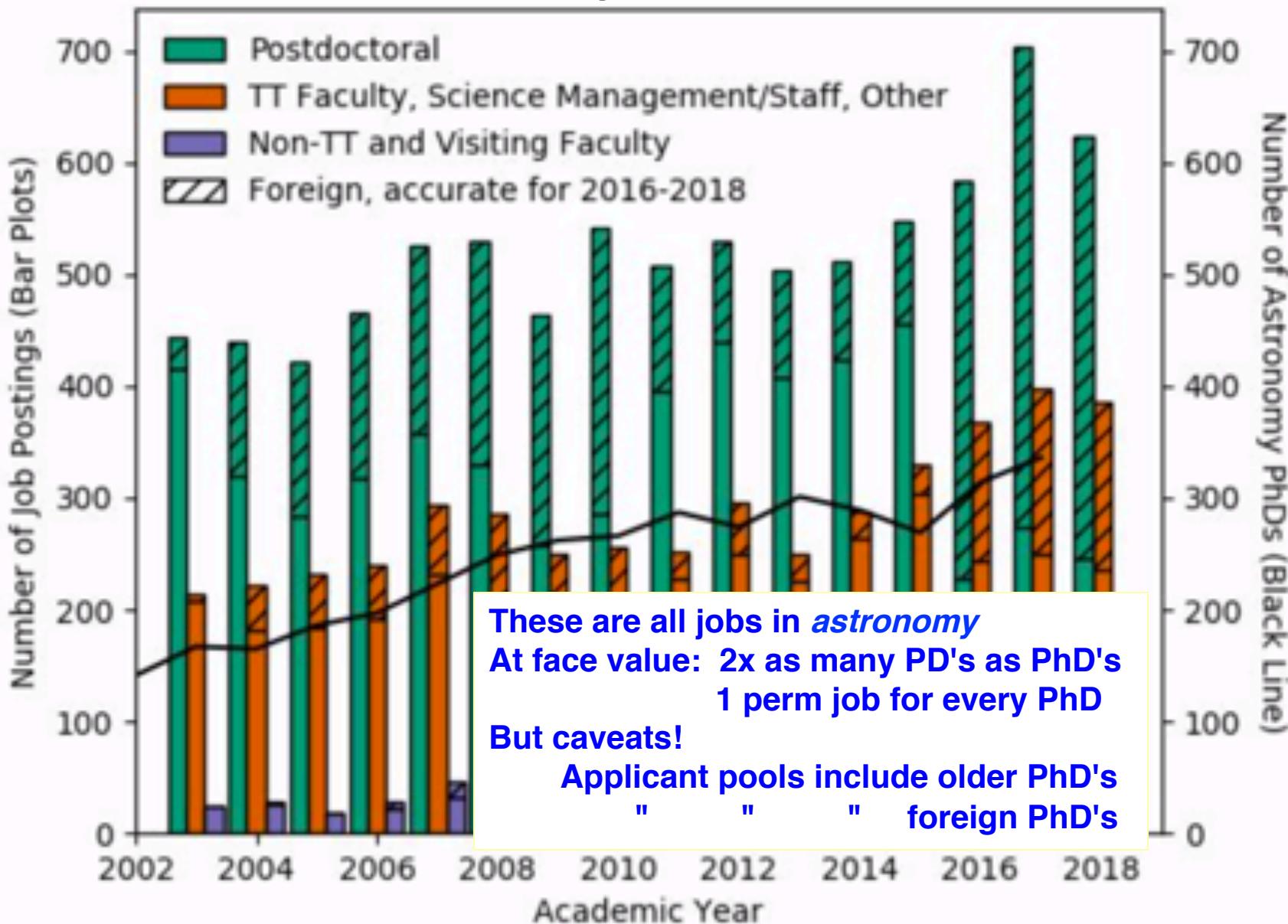
# AAS Job Register Statistics



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

## Metcalf 2008

PUBLICATIONS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, 120:229–234, 2008 February  
© 2008. The Astronomical Society of the Pacific. All rights reserved. Printed in U.S.A.

### The Production Rate and Employment of Ph.D. Astronomers

TRAVIS S. METCALFE

High Altitude Observatory and Scientific Computing Division, National Center for Atmospheric Research, Boulder, CO; travis@hao.ucar.edu

Received 2007 August 05; accepted 2007 December 19; published 2008 February 19

**ABSTRACT.** In an effort to encourage self-regulation of the astronomy job market, I examine the supply of, and demand for, astronomers over time. On the supply side, I document the production rate of Ph.D. astronomers from 1970 to 2006 using the UMI Dissertation Abstracts database, along with data from other independent sources. I compare the long-term trends in Ph.D. production with federal astronomy research funding over the same time period, and I demonstrate that additional funding is correlated with higher subsequent Ph.D. production. On the demand side, I monitor the changing patterns of employment using statistics about the number and types of jobs advertised in the AAS Job Register from 1984 to 2006. Finally, I assess the sustainability of the job market by normalizing this demand by the annual Ph.D. production. The most recent data suggest that there are now annual advertisements for about one postdoctoral job, half a faculty job, and half a research/support position for every new domestic Ph.D. recipient in astronomy and astrophysics. The average new astronomer might expect to hold up to 3 jobs before finding a steady position.

*Online material:* color figures

# 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/ab9cc4>



### 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](mailto: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  $\cdot$ post-Ph.D. of  $H_{F/M} = 1.08^{+0.20}_{-0.15}$  and a leaving probability ratio of  $L_{F/M} = 1.03^{+0.10}_{-0.04}$  (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

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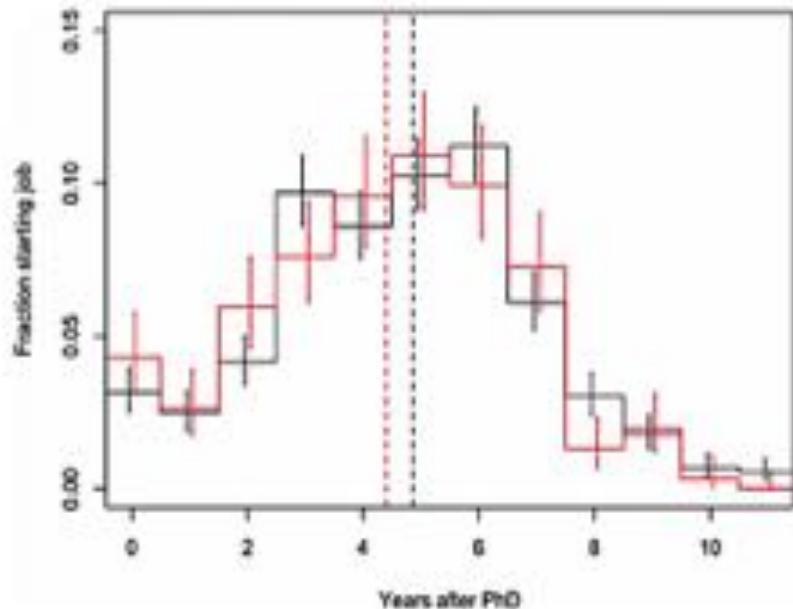
Astrophysics Research Institute, Liverpool John Moores University, IC2, Liverpool Science Park, 146 Brownlow Hill, Liverpool L3 5RF, UK; [d.a.perley@ljmu.ac.uk](mailto:d.a.perley@ljmu.ac.uk)  
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Followed actual post-PhD histories of over 1100 individual 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

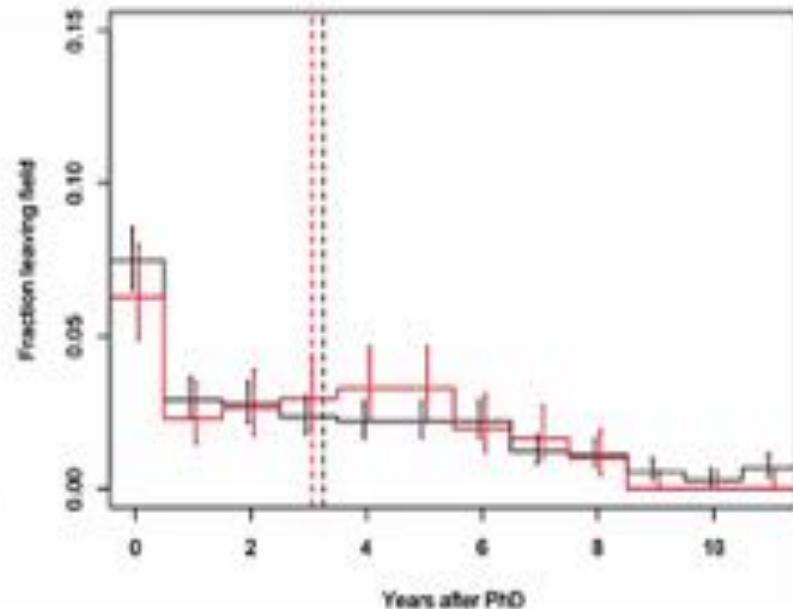
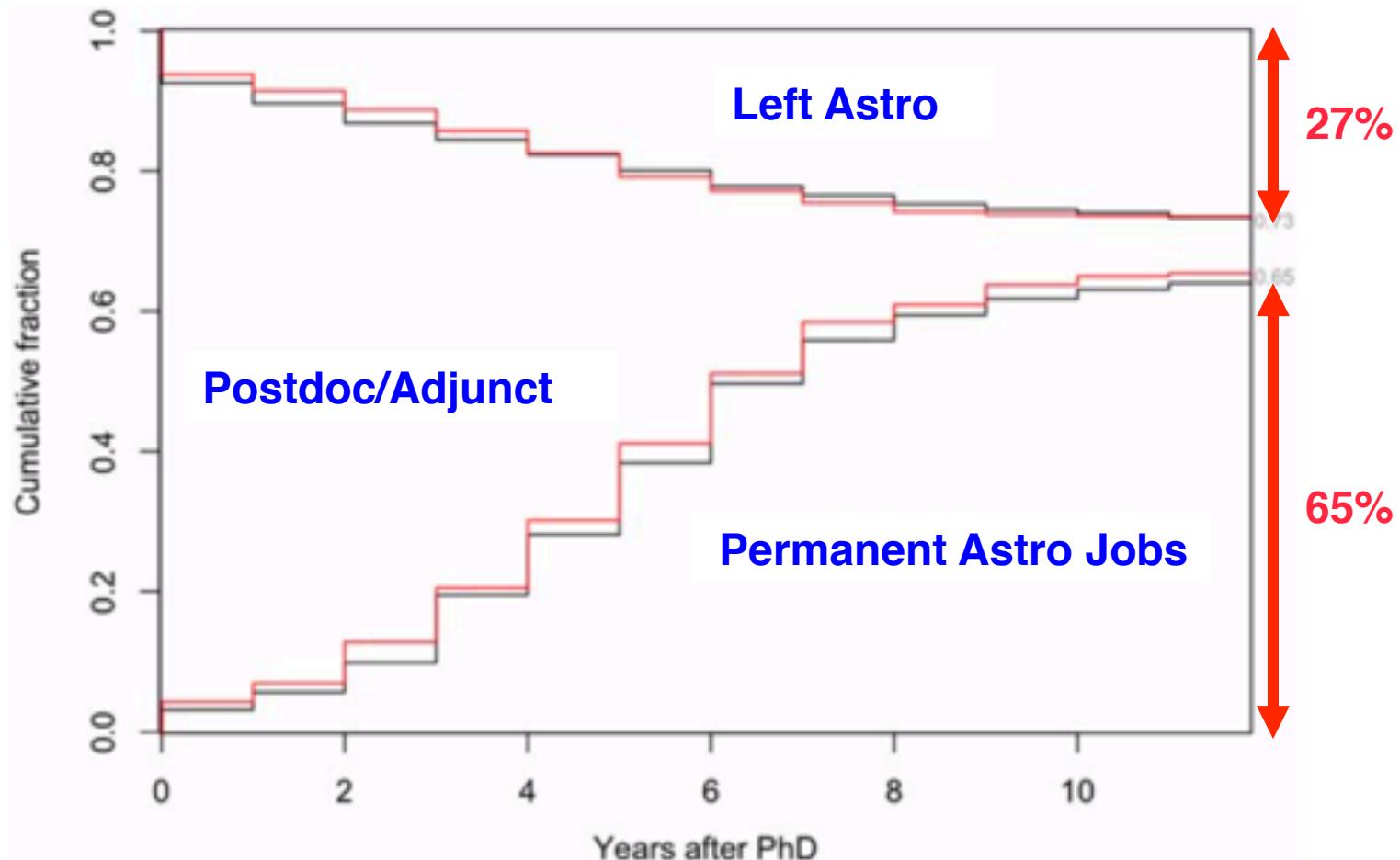


Figure 1. Histograms of recorded times (years after Ph.D.) at which Ph.D.s either: (left) progressed from term-limited to long-term or permanent positions within astronomy, or (right) left the field to pursue other employment. Histograms are normalized using total counts for each gender (regardless of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

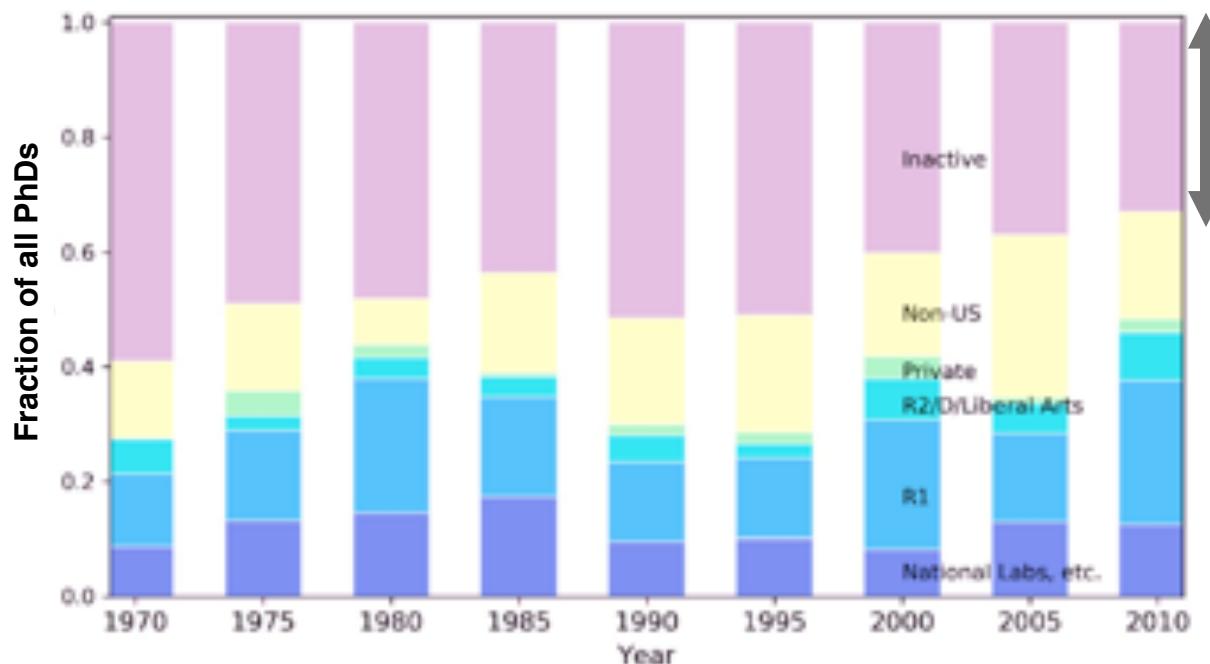
## 12-Year Cumulative Employment (Data 2000-2012)



# 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 within the field.*" [Data for 2018]

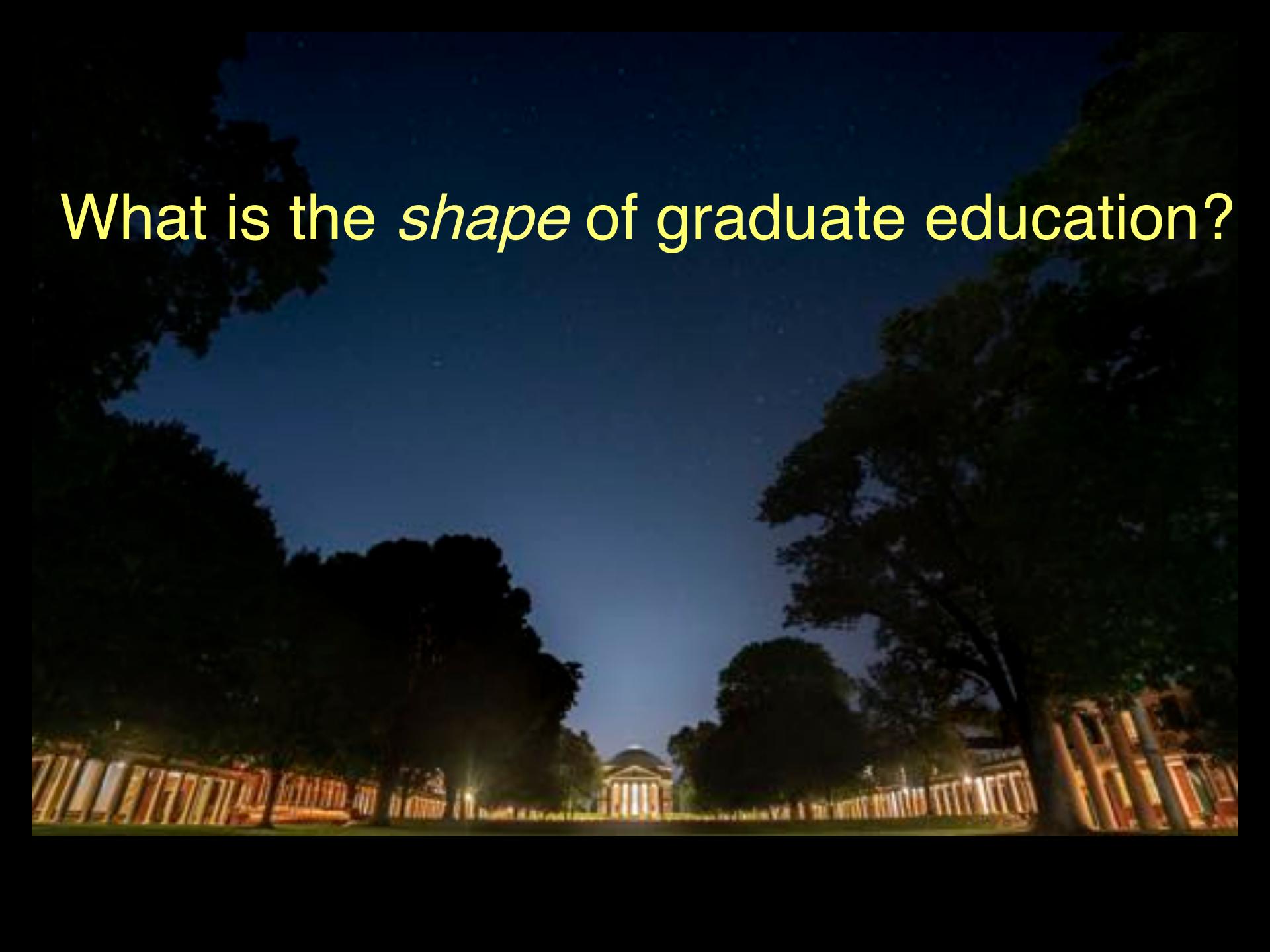
Kamenetzky (2019): "*The overall number of permanent positions in the astronomical sciences has steadily increased in recent years, from ~300 in 1999 to ~380 per year in 2018. This increase occurred ~10 years earlier, roughly coincident with the increase in new PhDs.*"

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

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]

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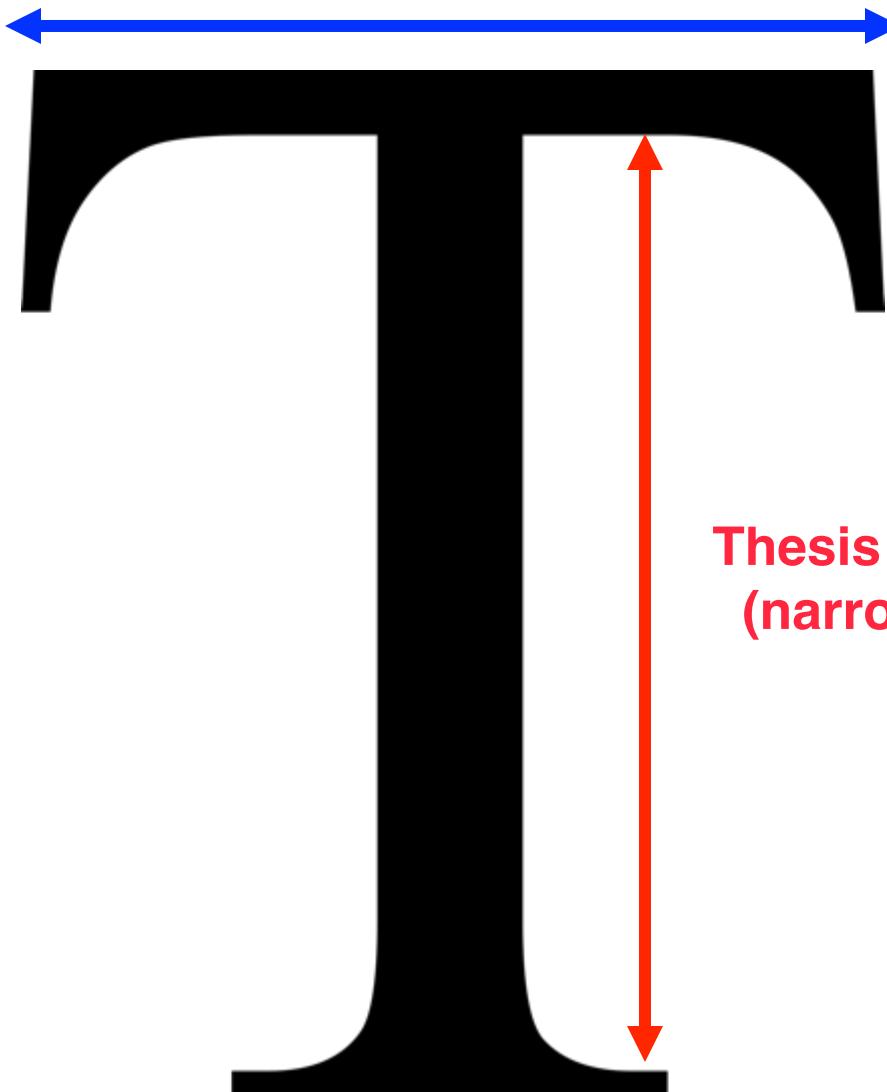
**"Available data suggest that [the number leaving the profession] has been much higher than 20% in the past decade."**

A nighttime photograph of a large, well-manicured lawn. In the background, a building with a prominent dome is visible, illuminated from within. The lawn is bordered by rows of trees on both sides, their silhouettes dark against the night sky. The foreground is a dark, flat expanse of grass.

What is the *shape* of graduate education?

IT

**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)

# *Numbers You Should Know*

## Part 2

ASTR 8500

Spring 2020

Robert W. O'Connell

# 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)**

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

~98(?)%

98(?)% of scientists  
love *most* of what  
they do

# *Life as a Faculty Member*



The background image shows the Rotunda at the University of Virginia, a neoclassical building with a prominent dome and porticos, set against a dark blue sky at dusk or night. Large trees frame the building on both sides.

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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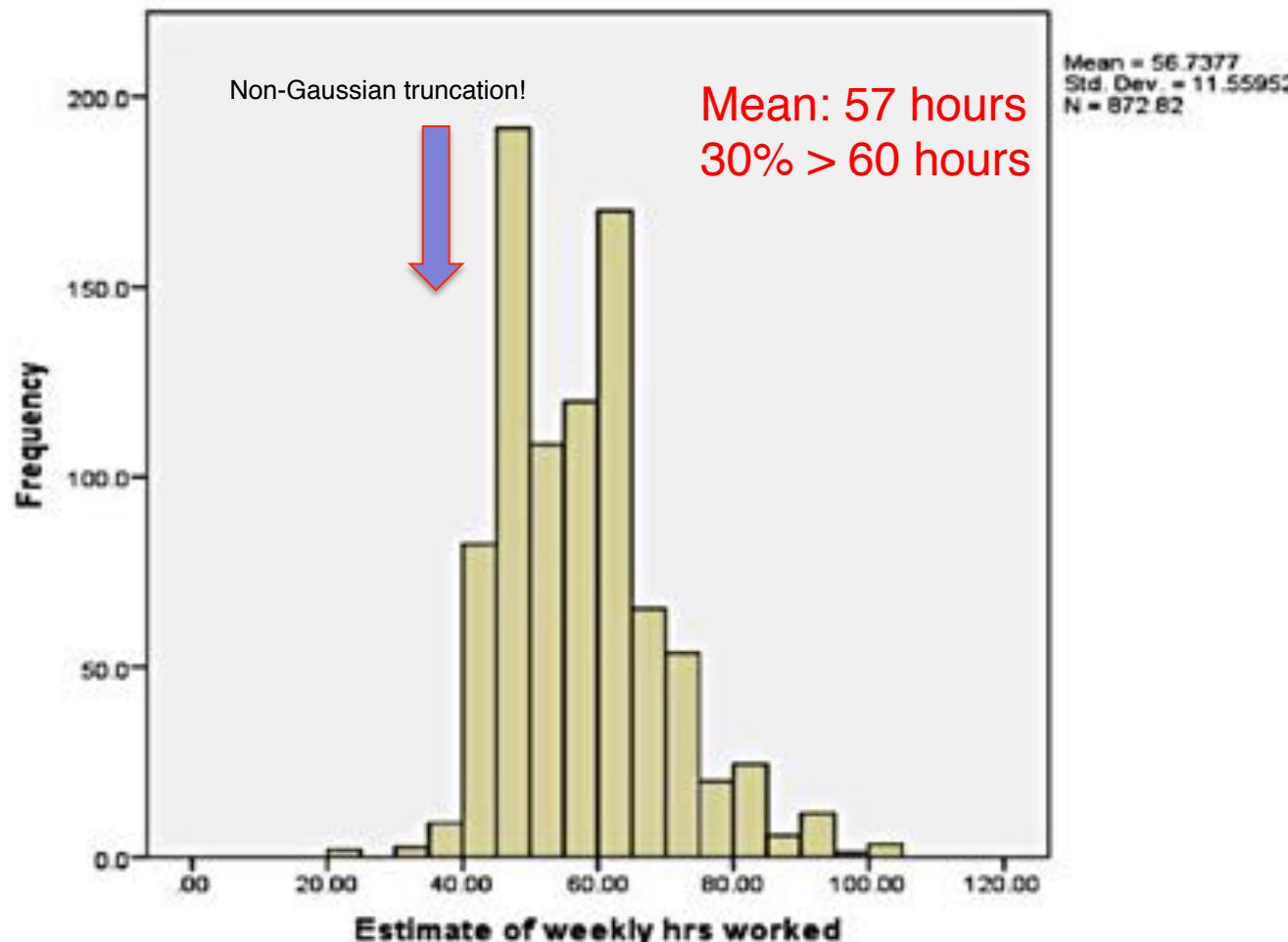
Almost no middle management

~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.



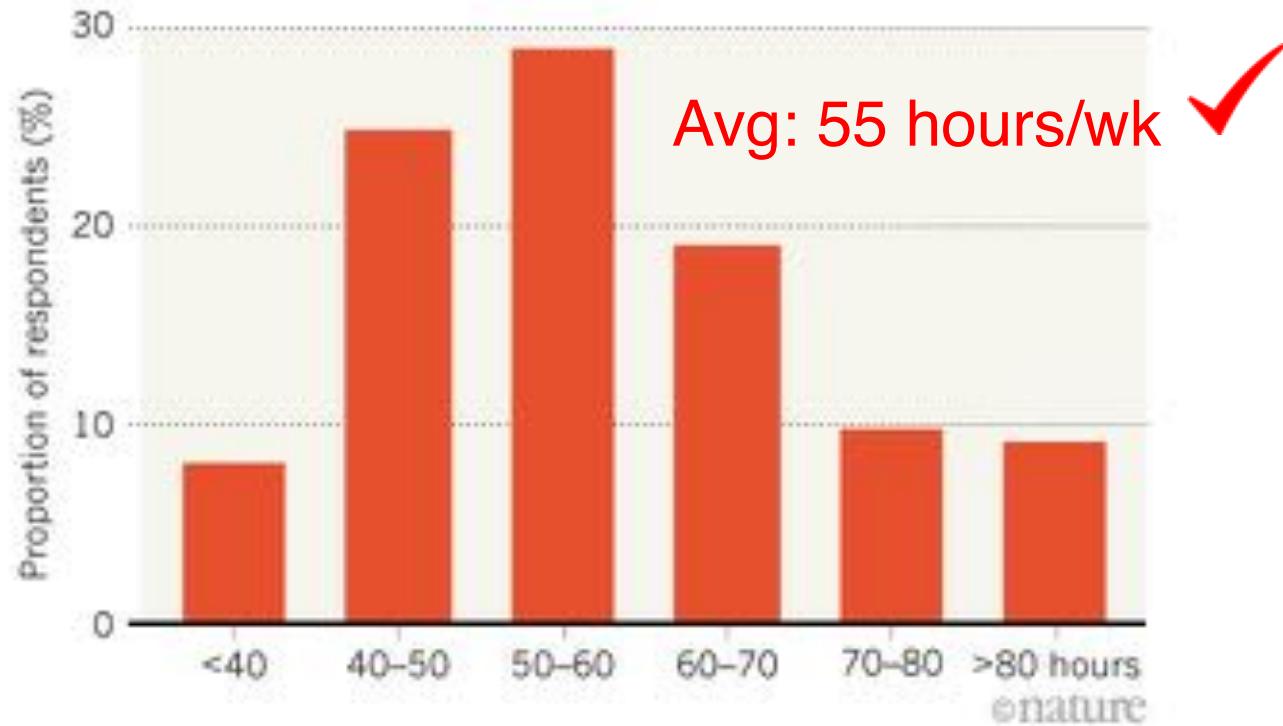
# Scientist Survey: Hours Worked (Nature)

## 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)



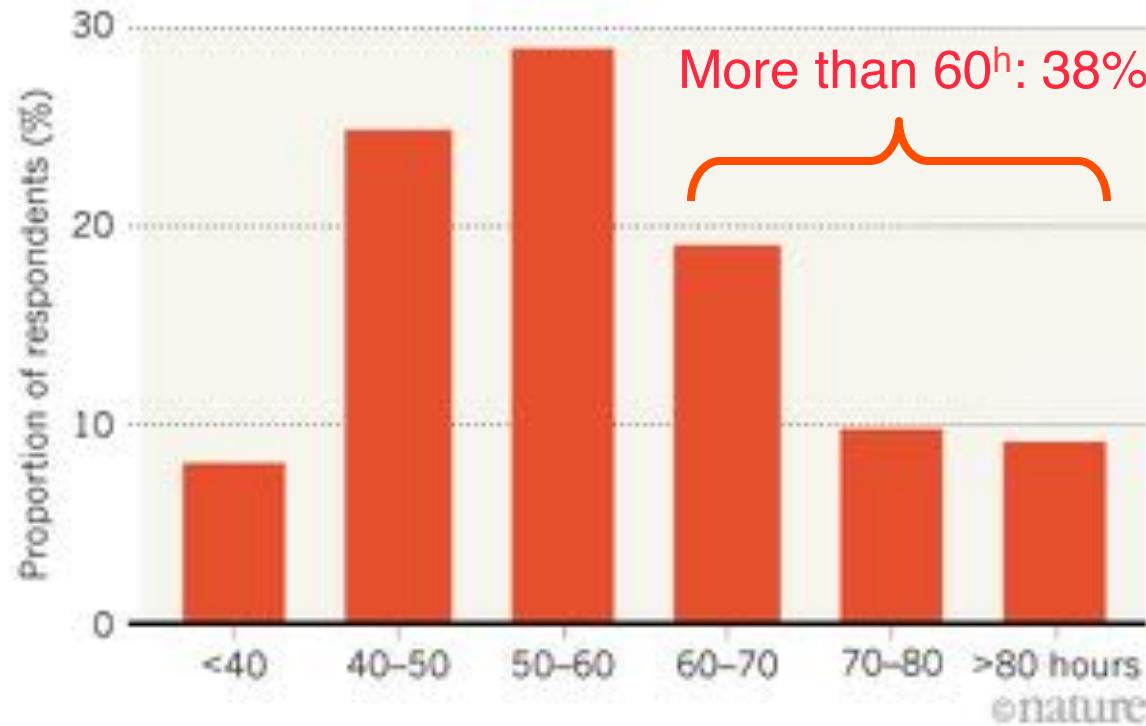
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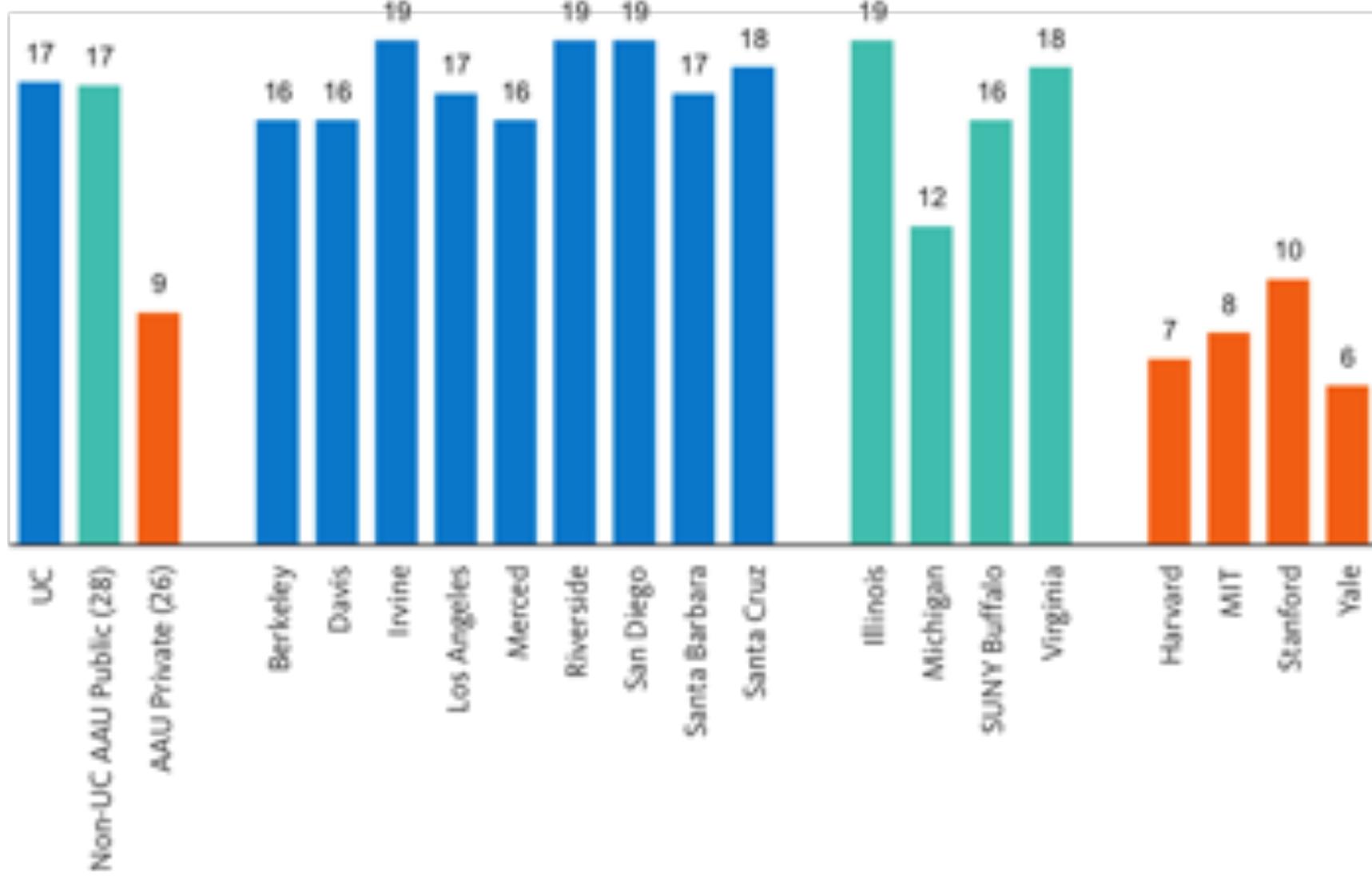


**~90-200**

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

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

# Student/Faculty Ratios





$\approx 7:1$

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

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

# New burden for faculty! 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



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

A large, dimly lit auditorium filled with people, viewed from behind. In the foreground, a bright orange diagonal banner runs across the slide. The banner features the words "OPTIONAL TOPIC: 'HOW TO GIVE A BAD TALK'" in large, bold, black capital letters.

# OPTIONAL TOPIC: "HOW TO GIVE A BAD TALK"

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

# Astronomy Education Review

Volume 6  
Issue 1

## Facts of Life for New Teachers in the Astronomy Nonmajors Curriculum

by Robert W. O'Connell

University of Virginia

Received: 03/15/07, Revised: 05/22/07, Posted: 08/03/07

The Astronomy Education Review, Issue 1, Volume 6, 2007

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### Abstract

This is a guide to the most pertinent or difficult practical issues that confront new teachers in the astronomy nonmajors curriculum at large colleges and universities. It covers topics such as course design and infrastructure, required effort, special considerations in nonmajors teaching, classroom performance, use of visual presentations and the Web, interactions with students, interactions with faculty research, and many details of recommended practice in the face of constraints imposed by the quality of students and the amount of institutional support.

### Table of Contents

- I. Introduction
- II. The Astronomy Nonmajors Curriculum
- III. Elements of Teaching
- IV. Goals
- V. Content and Texts
- VI. Effort
- VII. The Teaching/Research Balance
- VIII. Special Effort Required in Nonmajors Teaching
- IX. General Tips
- X. Your Student Target Audience
- XI. Interactions with Students
- XII. Assignments, Innumeracy, Quantitative Work, Critical Thinking
  - A. Expected Work
  - B. Science Literacy and Innumeracy

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MUST PLAN FOR HEAVY DEMANDS  
OF TEACHING ON YOUR TIME

# Job Profile of a Faculty Member

- Teaching
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  - Course, curriculum, & resource development/management
  - Student mentoring, advising, recommendations
  - Outreach
- Research
  - Personal - undirected
  - Supervising grad students
  - Management: lab, program, project, administering finances (grants)
- Service/Administration
  - Local, departmental, university, national administration: operations, governance, policies, personnel, hiring, tenure, promotion, grants, proposals, budgeting, proposals, reviews
  - Refereeing, reviewing, proposal reviews
  - Disciplinary committees, planning, meetings, advocacy
  - National agency policy, planning, review
- Consulting

**TIME MANAGEMENT  
AN ESSENTIAL SKILL**

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- Research
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  - Supervising grad students
  - Management: lab, program, project
  - Administering finances (grants)
- Service/Administration
  - Local: teaching, administration: operations, governance, policies, personnel, hiring, 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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~1/3 Research Scientists

~1/3 Non Astronomy

65%

(Perley 2019)

# "Non-Dedicated Astronomy"

Jobs draw on general training in high-tech field

Could be related to astronomy, but not necessarily

Examples:

Space science/applications (govt, contractors, commercial)

High-end computing (databases, AI)

Computational biology (genomics, neurology)

Instrumentation (sensors, imaging, optics)

Medical imaging



Be alert for opportunities to develop  
transferable knowledge and skills

3611

3611

= Largest number of authors  
on an astronomical paper

# The Rise of Group Science

ADS Statistics on published Ast/Ap papers

# Authors	<u>1975</u>	<u>2016</u>
1	40%	7%
>2	26%	78%
>5	3%	39%
Max # to date	40	1187

3611

= Largest number of authors  
on an astronomical paper.

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

Abbott et all !



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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, EPIC 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, GRAVITTA: GRAVitational Wave InflaTeAm, The Fermi Large Area Telescope Collaboration, ATCA: Australia Telescope Compact Array, ASKAP: Australian SKA Pathfinder, Las Cumbres Observatory Group, OfeGra, 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, RMAS and RATIR, and SKA South Africa/MorionKAT (See the end matter for the full list of authors.)

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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  $31 \text{ deg}^2$  at a luminosity distance of  $40^{+5}_{-3}$  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 Blaude & 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 astrophysics 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; Mseshevitch 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; Wu 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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## Multi-messenger Observations of a Binary Neutron Star Merger\*

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GROUPS,  
not people



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- 62 collaborations
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- 3611 authors
- Author list is 10 pages long
  - (Normal ApJL total length is 4 pgs)
- 953 institutional affiliations
- Acknowledgements take 6 pgs
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Multimessenger search for sources of gravitational waves and high-energy neutrinos: Initial results for LIGO-Virgo and IceCube

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PARTICIPATION & MANAGEMENT**

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

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**OPTIONAL TOPIC: "NAVIGATING GROUP SCIENCE"**



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