Numbers You Should Know
Part 1

A semi-quantitative profile of the profession

ASTR 8500 Spring 2024 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. Introduction

Course Assignments

Optional Topic List

B. Profile of the Profession

Numbers You Should Know (O'Connell 2024)

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)
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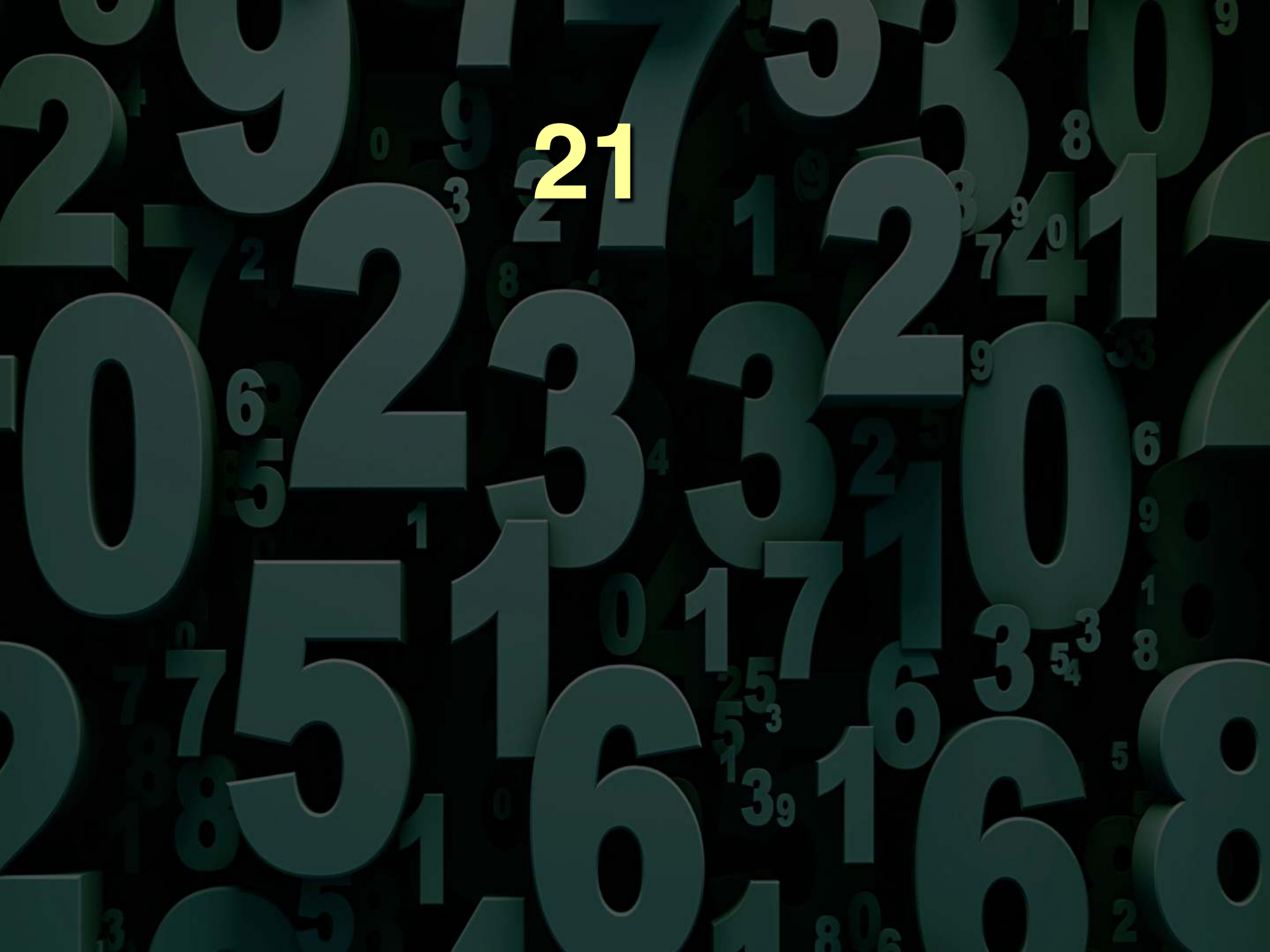
Consolidated Faculty Advice, 2022

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

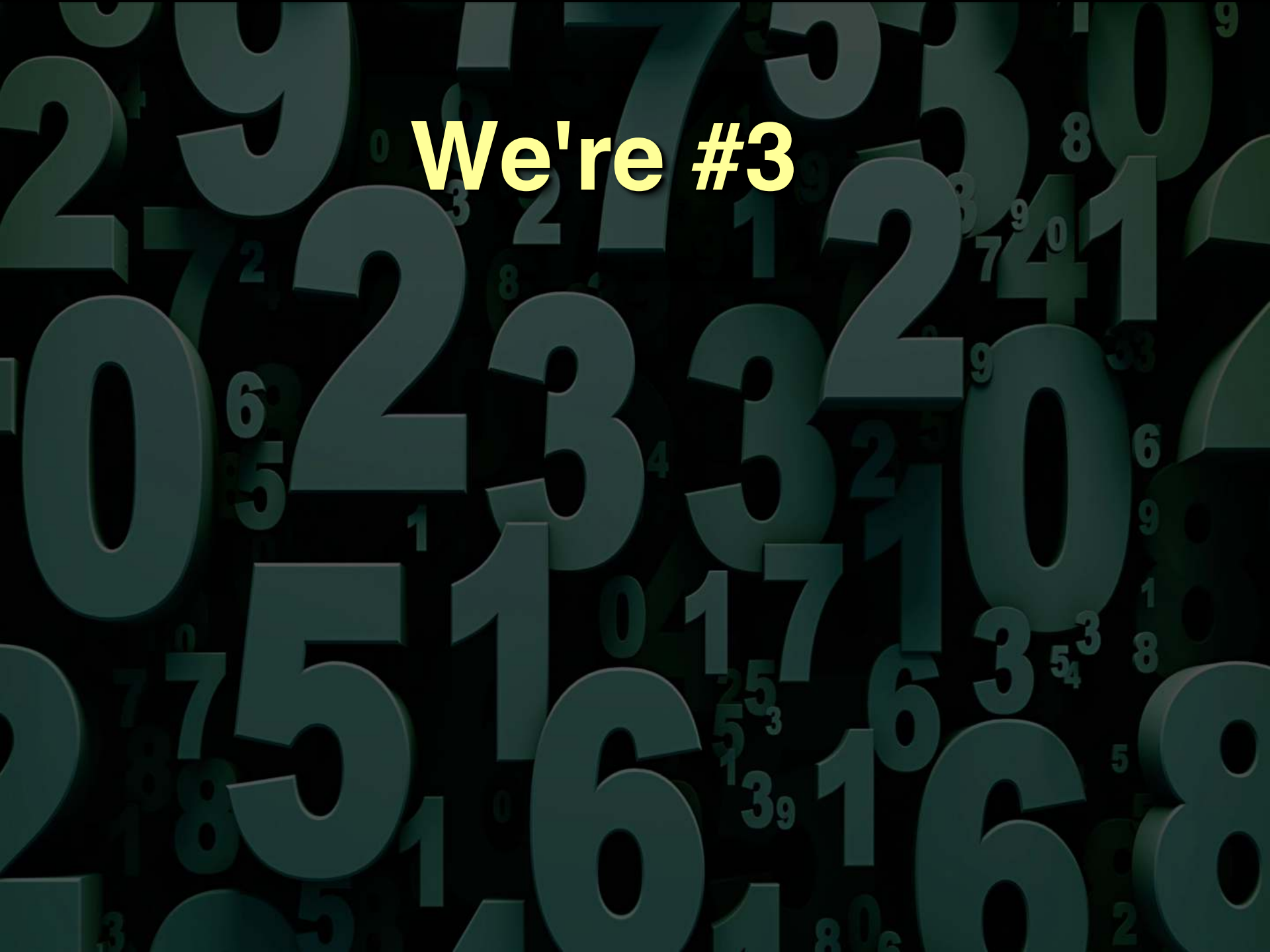
A National Perspective on Astronomy


21

Century 21

An apex of astronomical discovery!

Cosmology, galaxy formation, galaxy evolution, black holes & neutron stars, astrochemistry, planet formation, exoplanets, exobiology, gravitational waves, SS planetary exploration


We're #3

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

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

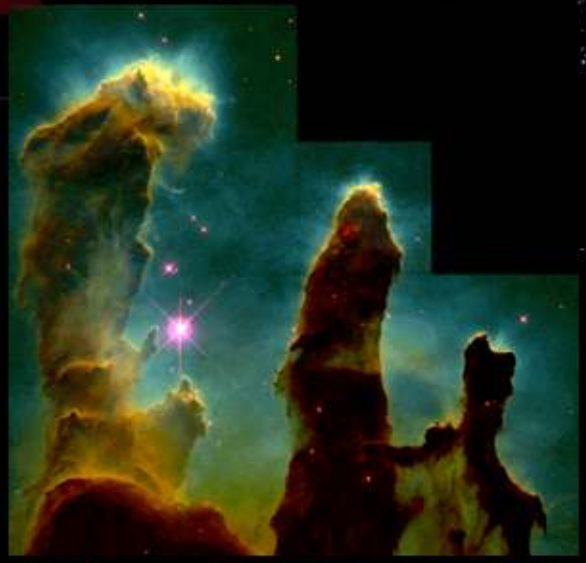
We're #1 in impact per practitioner!

Total STEMM employment: 16 million

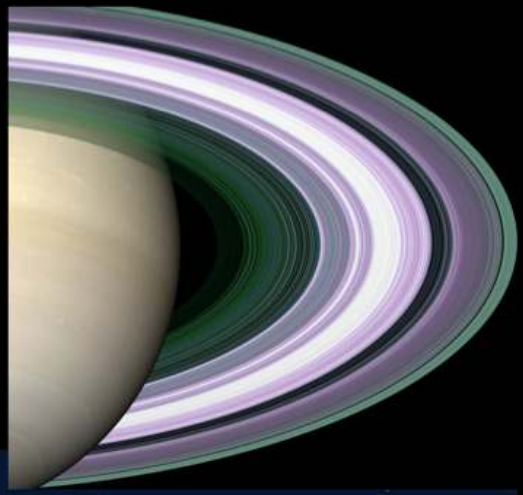
Total astronomy & space science employment: ~20-30 thousand

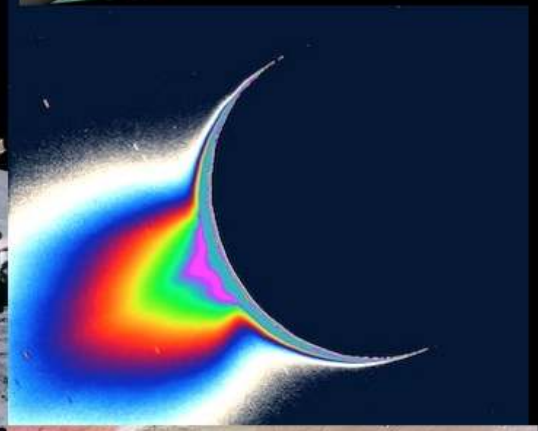


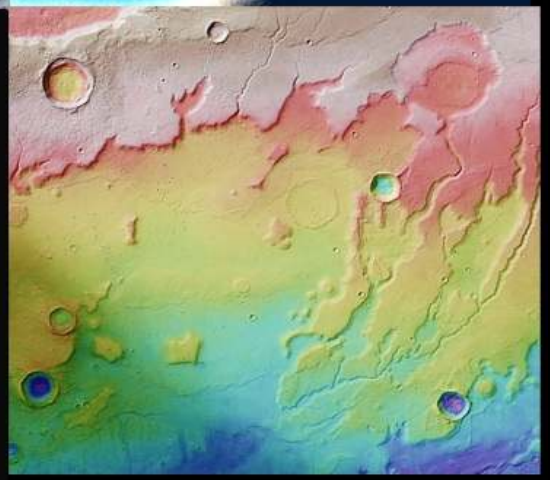


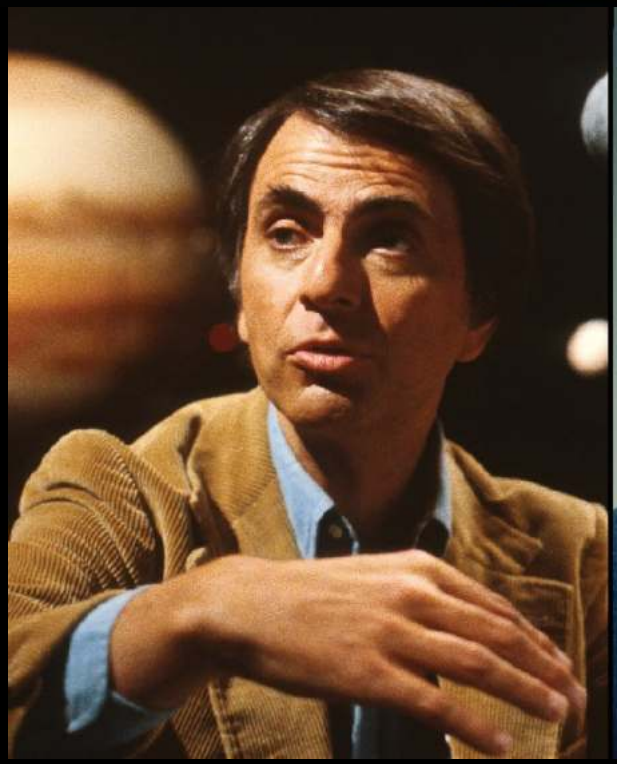




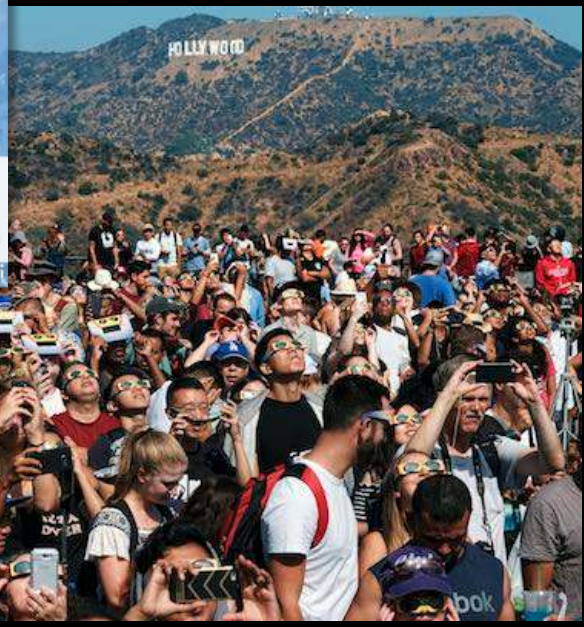


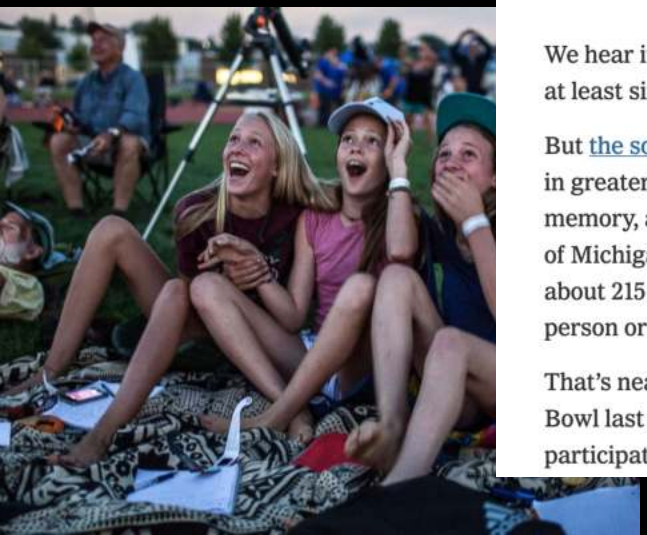


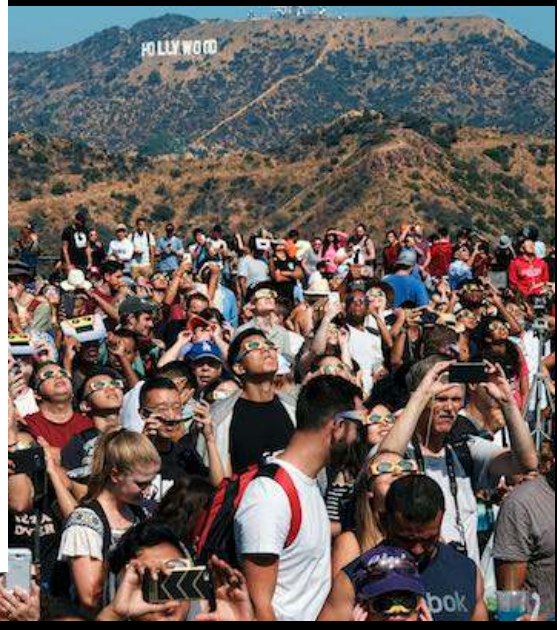




Eclipse USA 2017







The New York Times

215 Million Americans Watched the Solar Eclipse, Study Finds

Todd Heisler/The New York Times

By Jonah Engel Bromwich

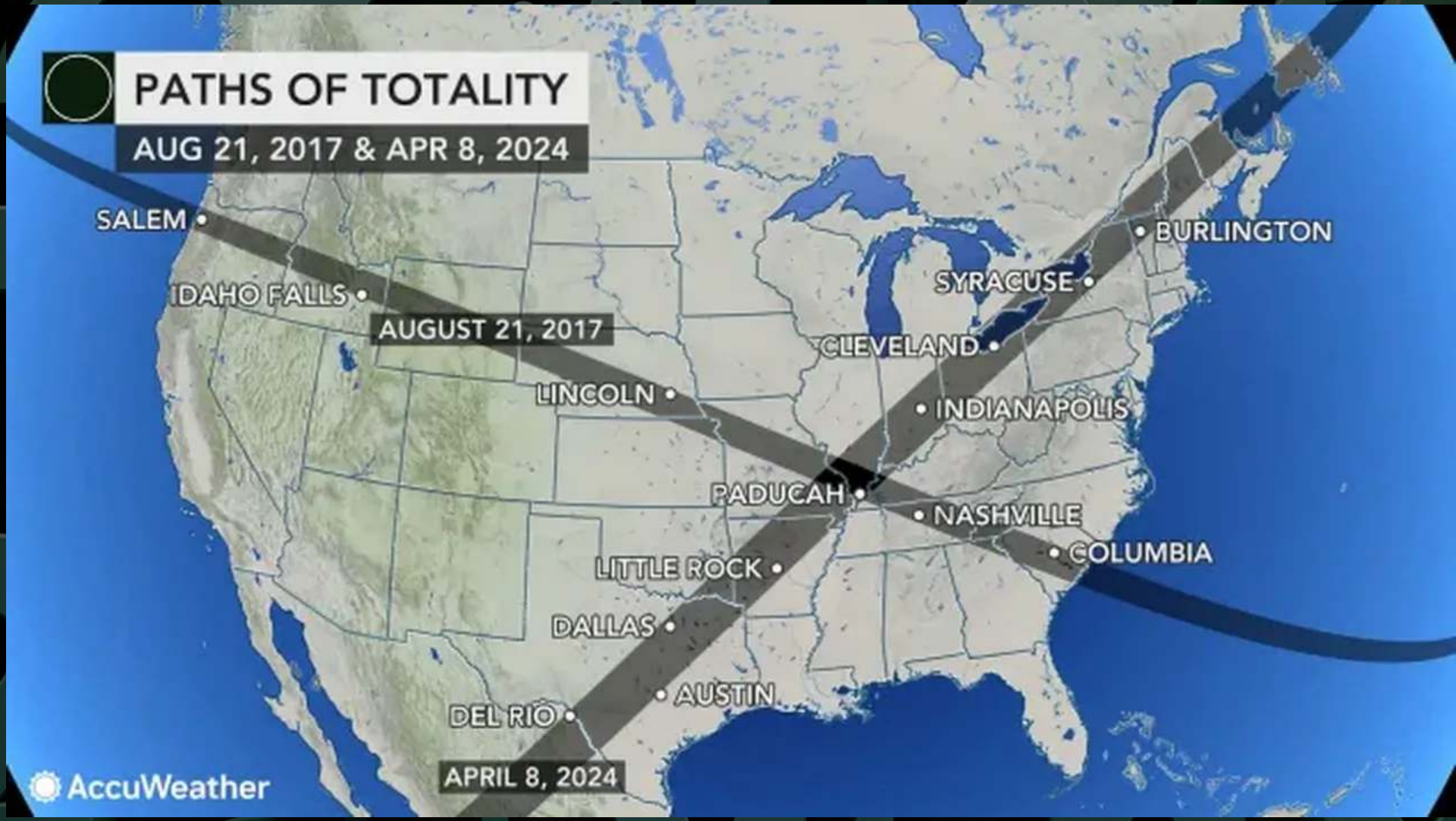
Sept. 27, 2017

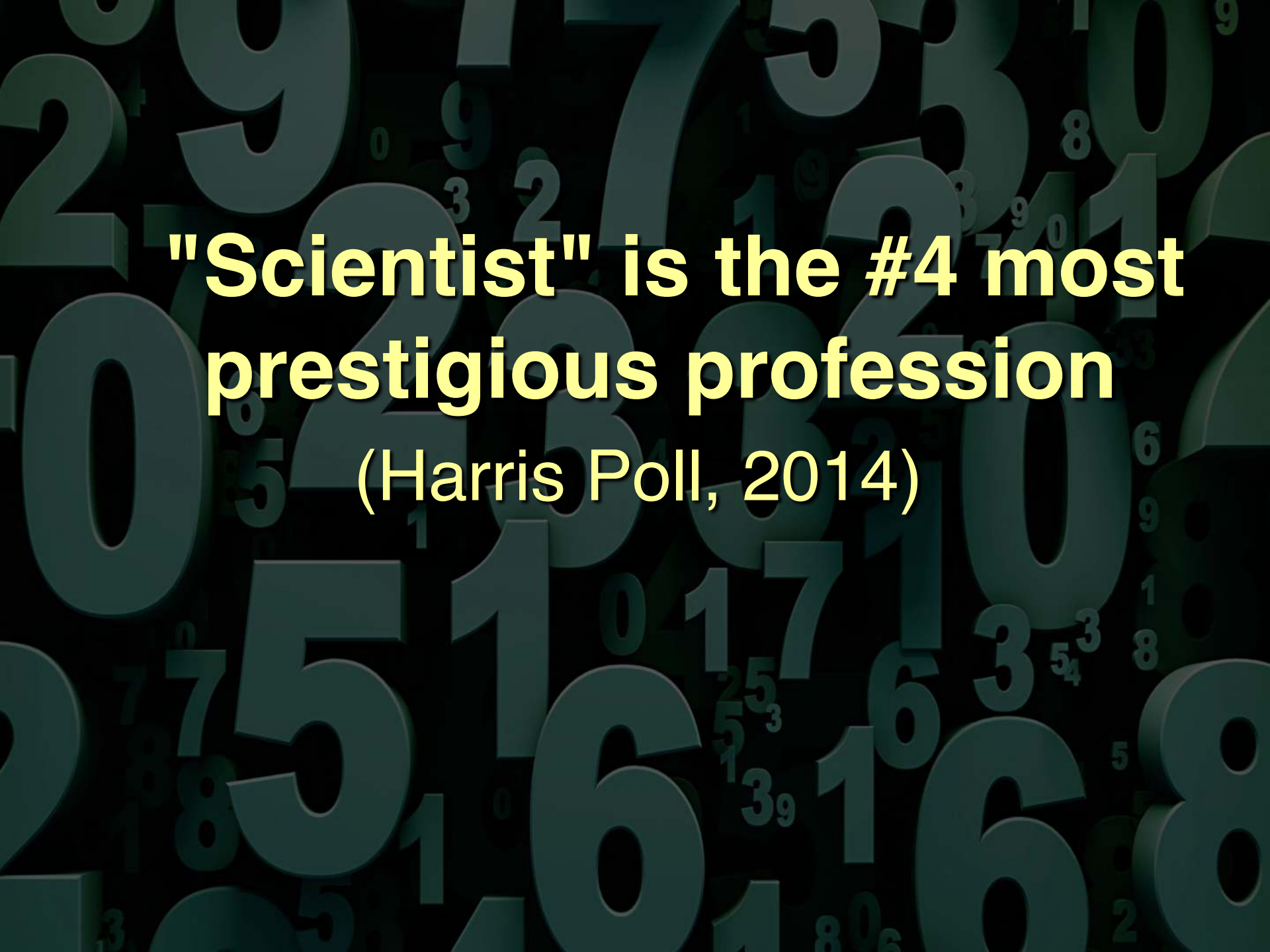
We hear it all the time: Americans are more divided than ever, or at least since the Civil War.

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.

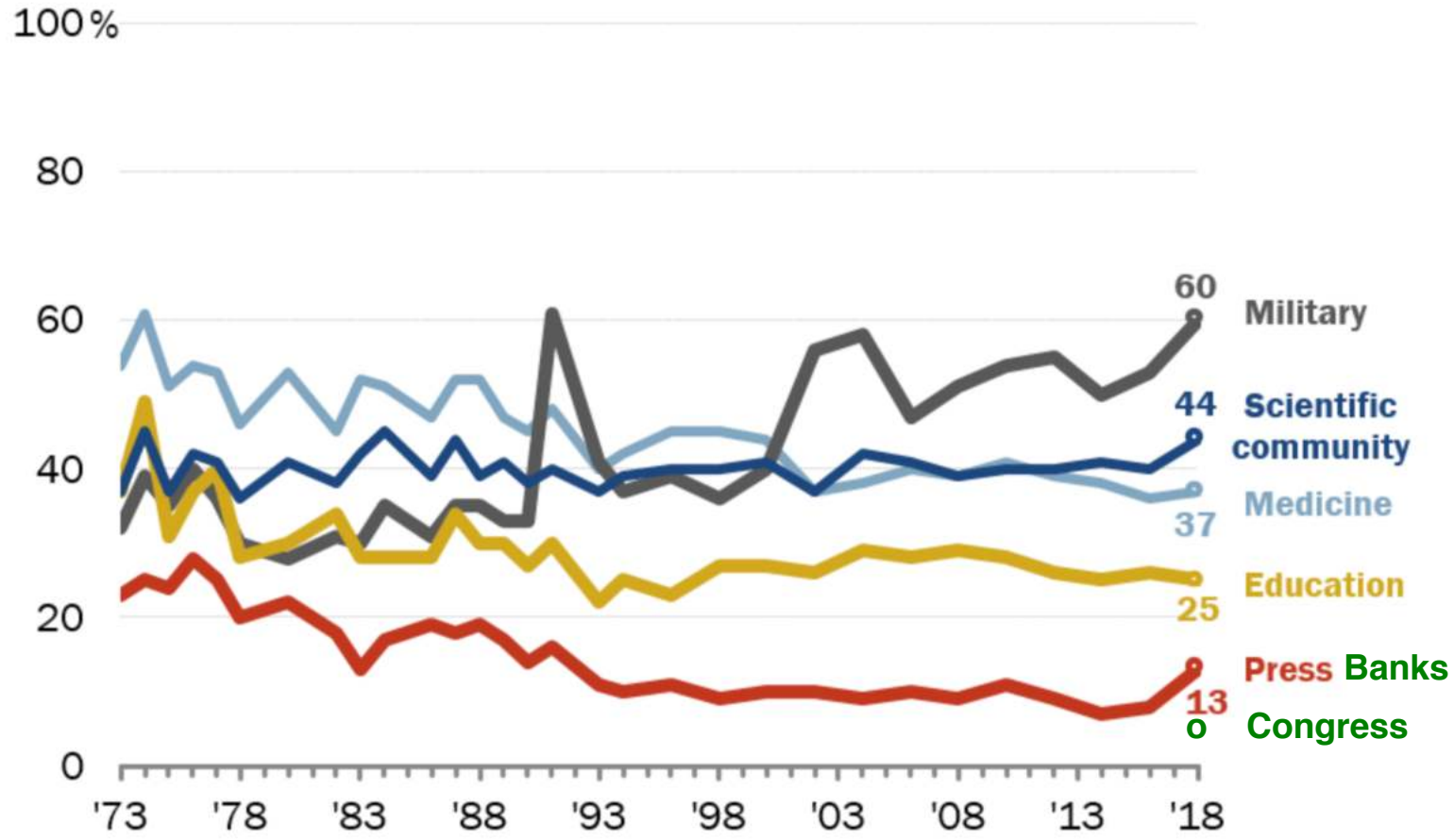
Doing it again! April 2024




"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 research 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.

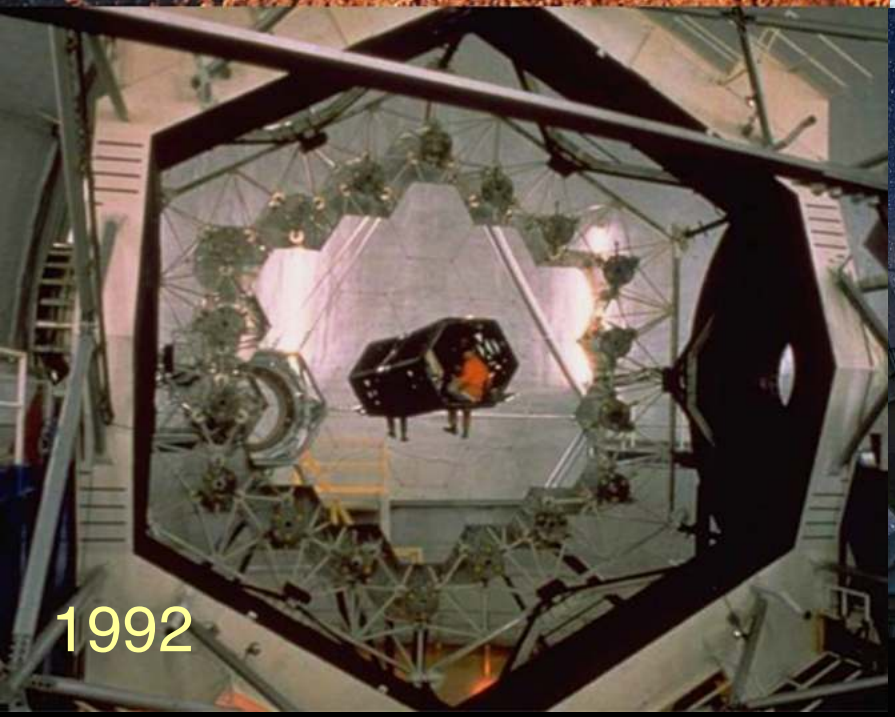
$425,000

= National budget for astronomy per astronomer

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


1974

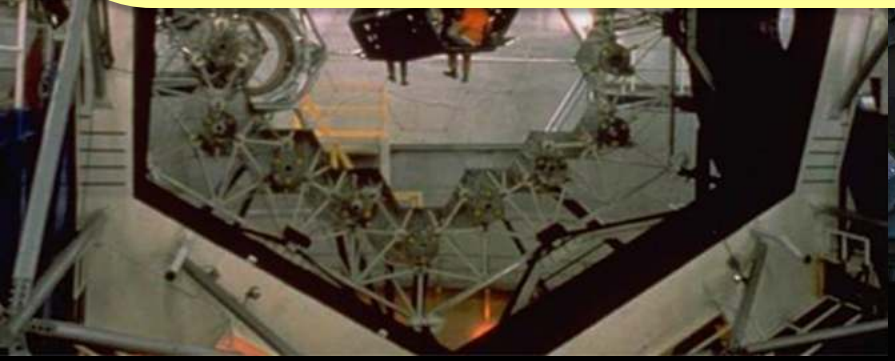

1990


1992

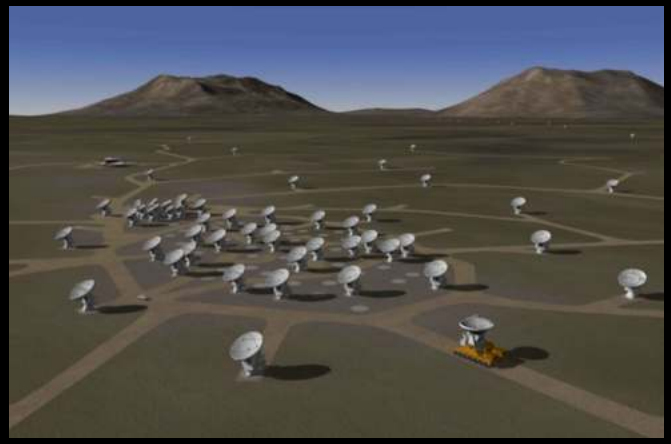

2011


Astronomy is ~uniquely dependent on large, shared experimental facilities

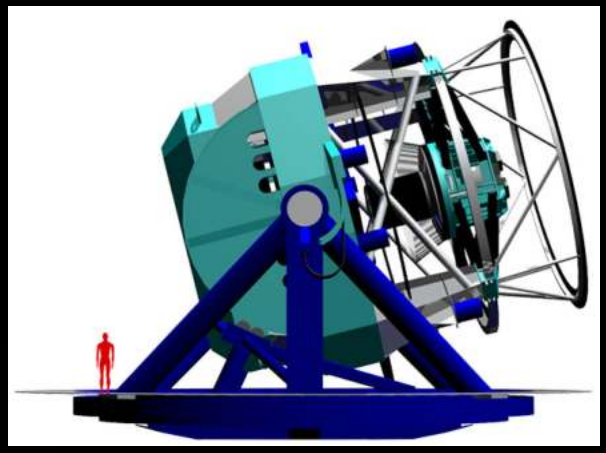
Astronomical facilities have long productive lifetimes; a blessing & a curse



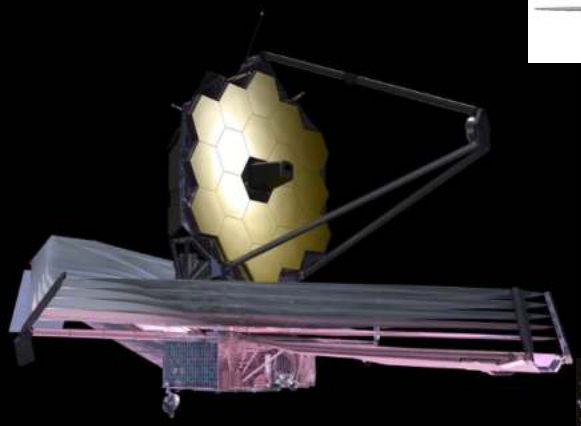

Promise of the 2020's



ALMA



Rubin/LSST



JWST

GMT

Roman/WFIRST


The Job Market

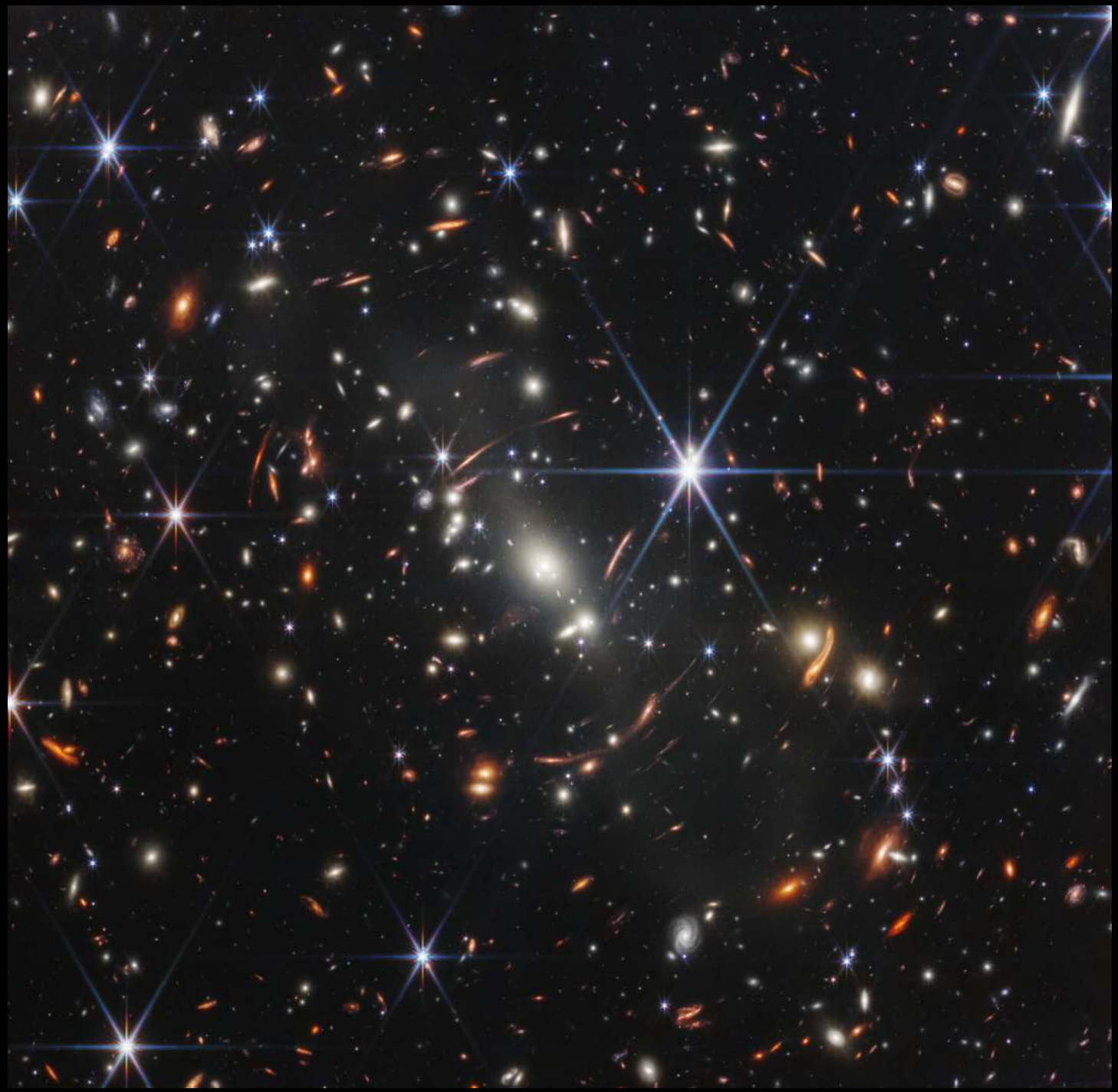
WHEW!

JAMES WEBB SPACE TELESCOPE

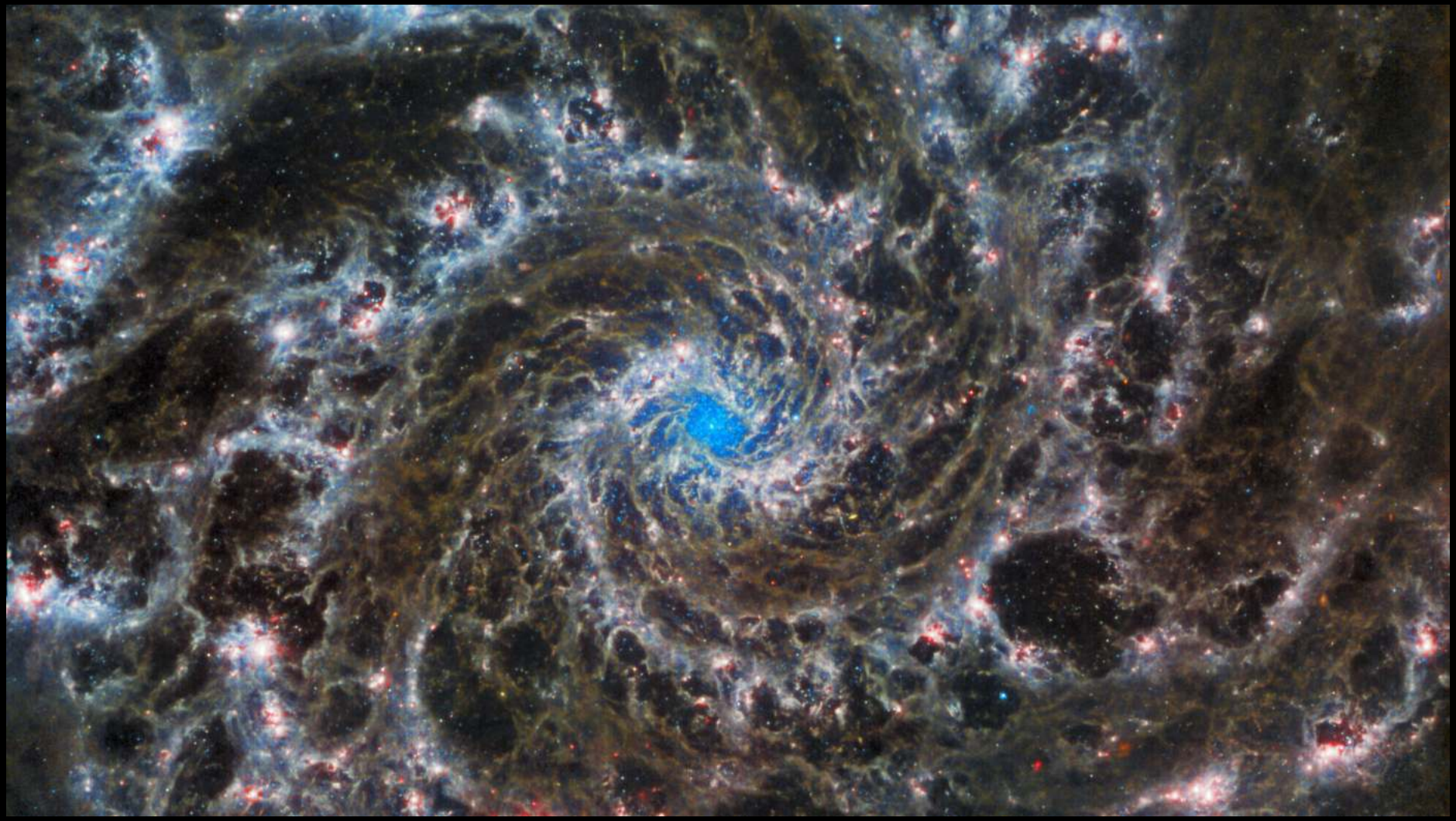
344 possible single point failures

....all avoided

$60M/year for GO programs



JWST: SMACS 0723



JWST: M74 NIR-MIR

Kinds of Jobs for PhD 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 $$$

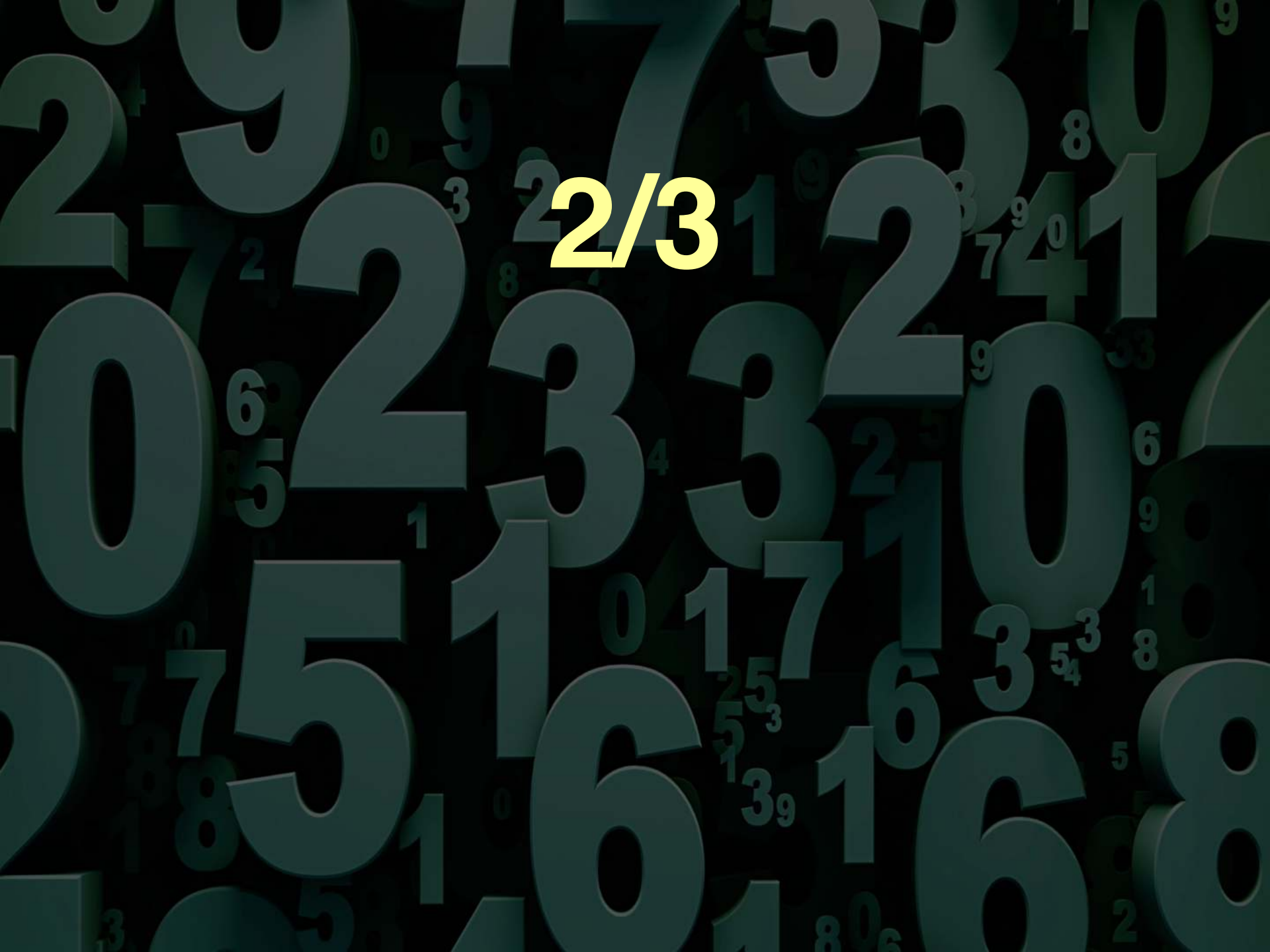
- **"Hard" money (reliable, long-term)**
  - Tenured faculty
  - Civil servants
  - Tenured & senior staff at national labs
- **"Soft" money (term-limited, grants, contracts)**
  - Postdocs
  - "Adjunct" faculty
  - Many "research scientists"
  - Federal contractors (e.g. SWRI)
  - Other private sector

2%

= Unemployment rate for astronomers

~ Transition rate

➔ ~ Full employment


2/3

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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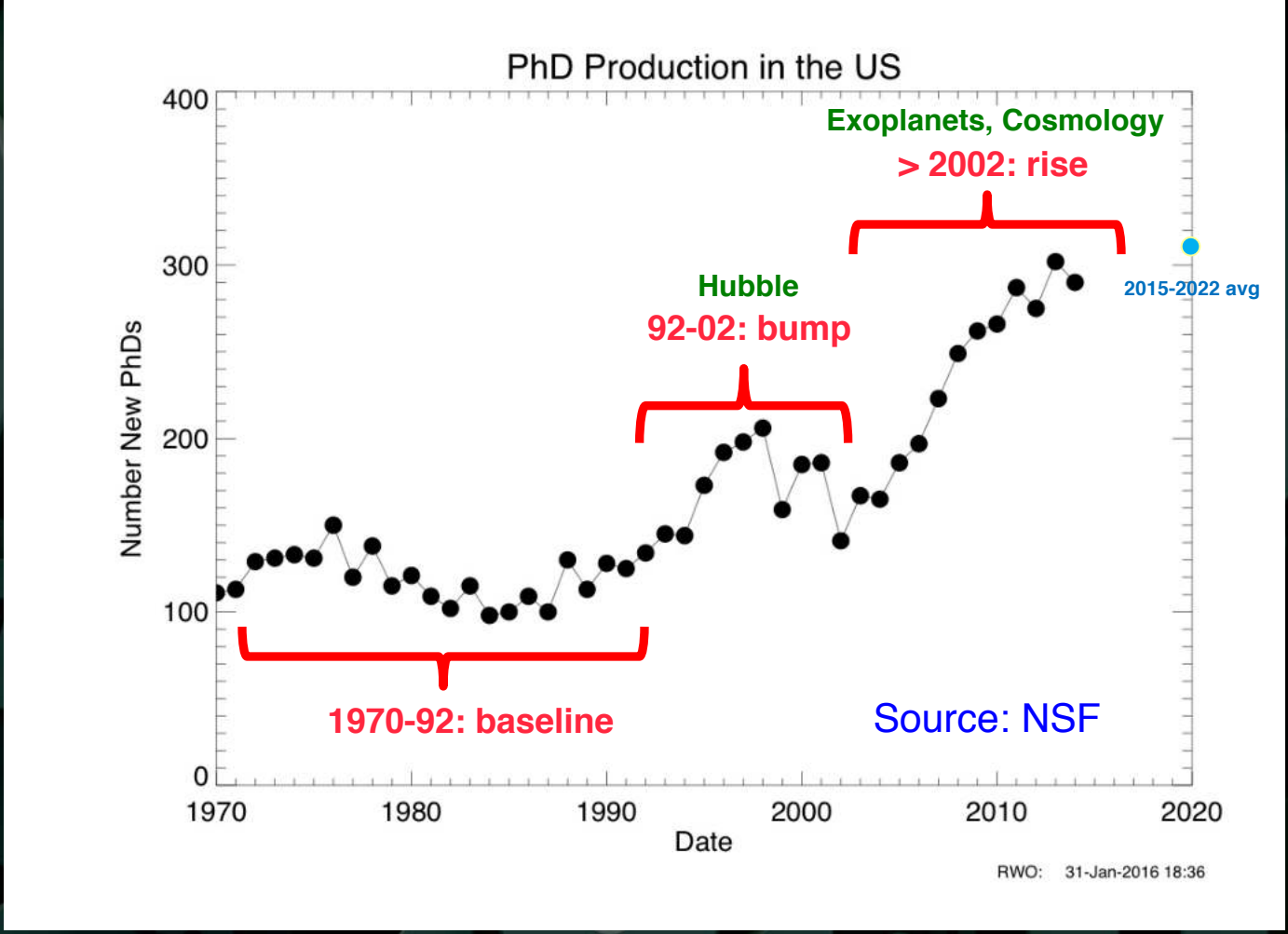
How many jobs?

~8500

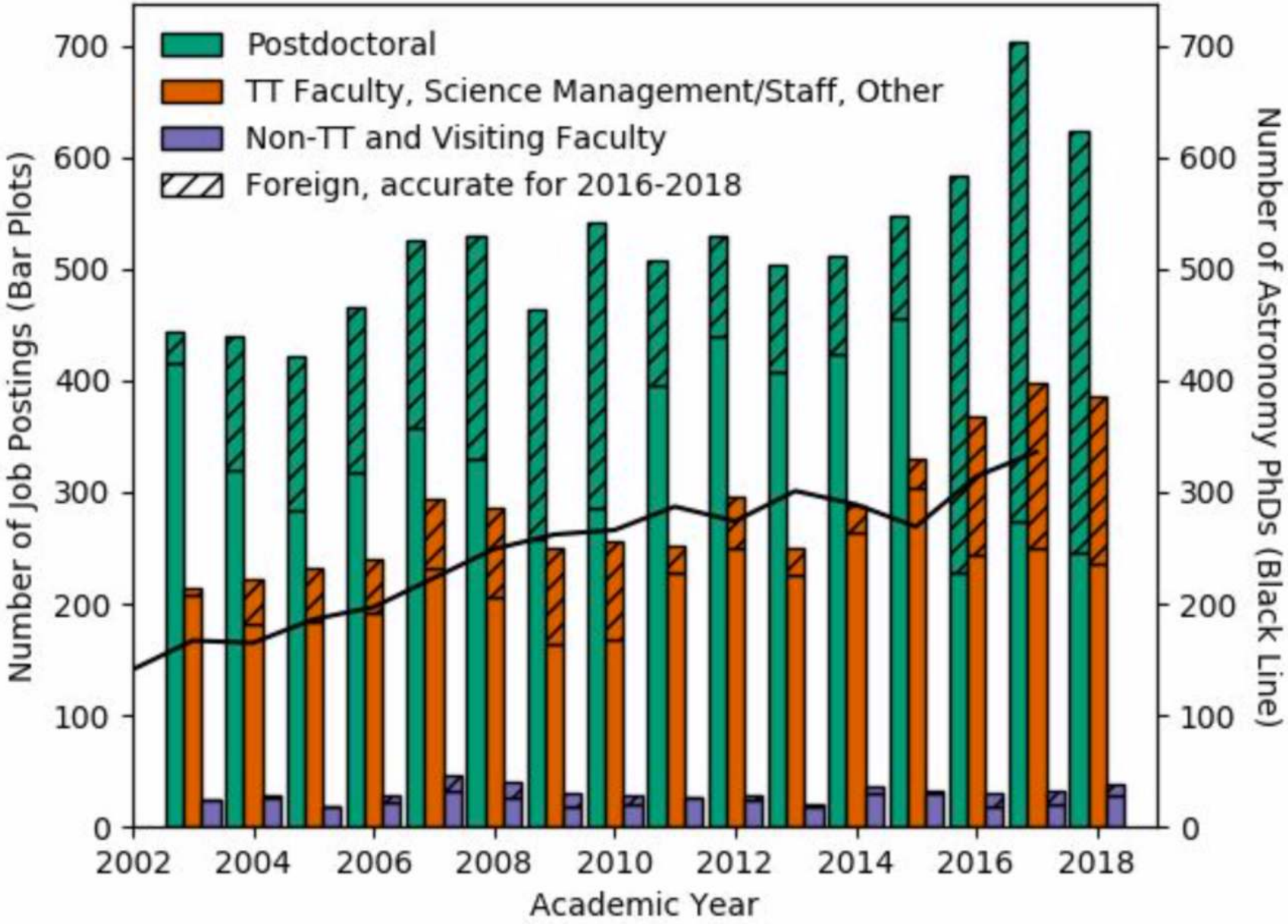
= Membership of AAS + Nonmembers

- Non-grad degrees

Production of New Astronomy PhD's



AAS Job Register Statistics



Black line: PhD's produced

(Kamenetzky, White Paper, 2019)

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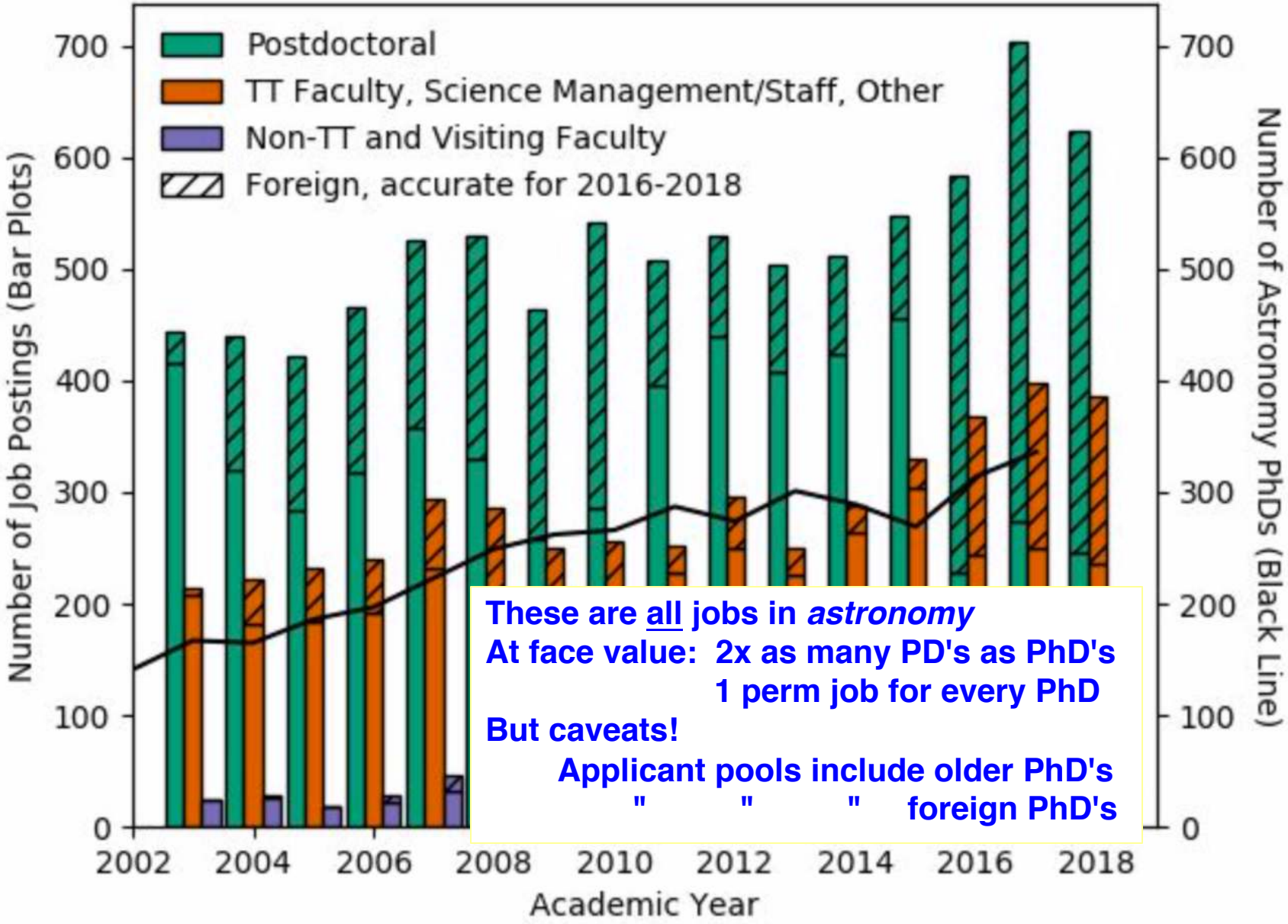

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Employment Demographics Studies

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

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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

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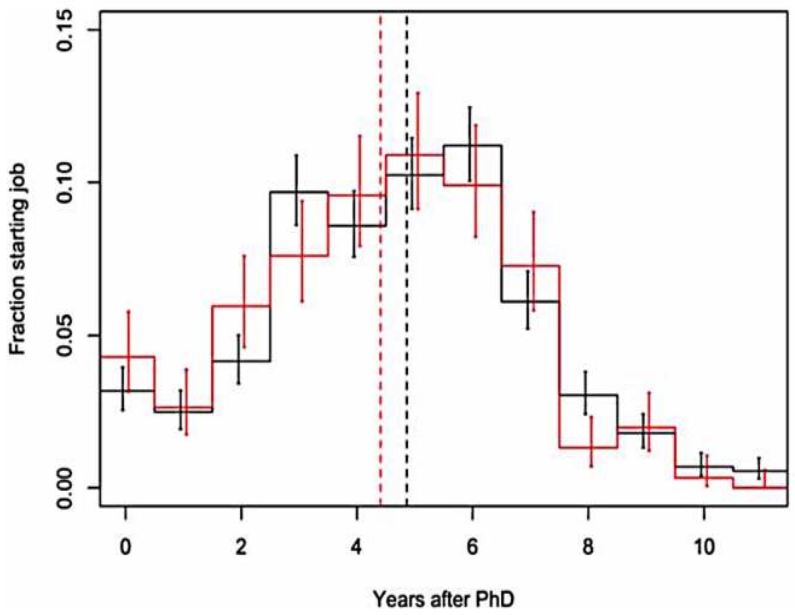
Followed actual post-PhD histories of over 1100 individual astronomers, unlike earlier studies using broad statistical measures or unreliable reporting (e.g. the "Rumor Mill" site).

Data for 2000-2012.

Perley 2019

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

Frac starting perm job



Frac leaving field

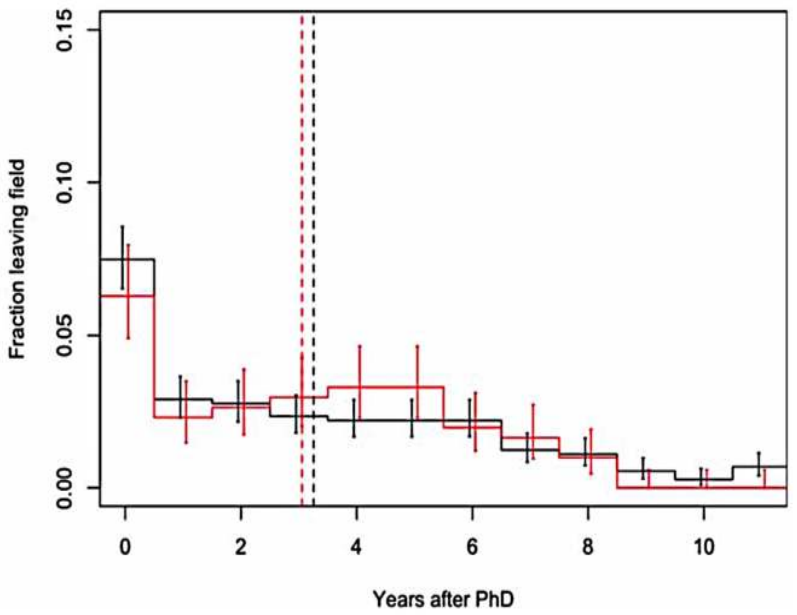
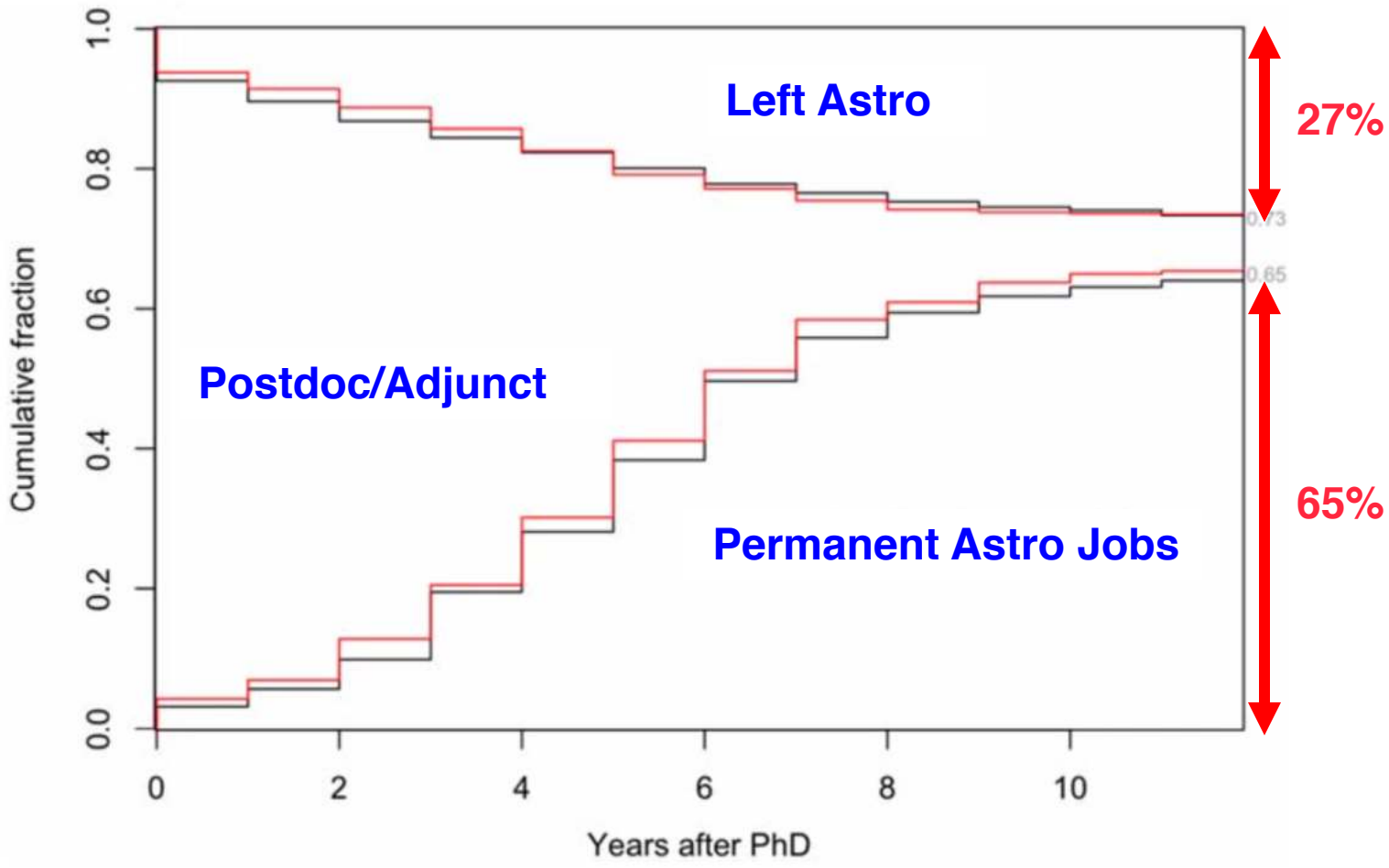


Figure 1. Histograms of recorded times (years after Ph.D.) at which Ph.D.s either: (left) progressed from term-limited to long-term or permanent positions within astronomy, or (right) left the field to pursue other employment. Histograms are normalized using total counts for each gender (regardless of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

Perley 2019

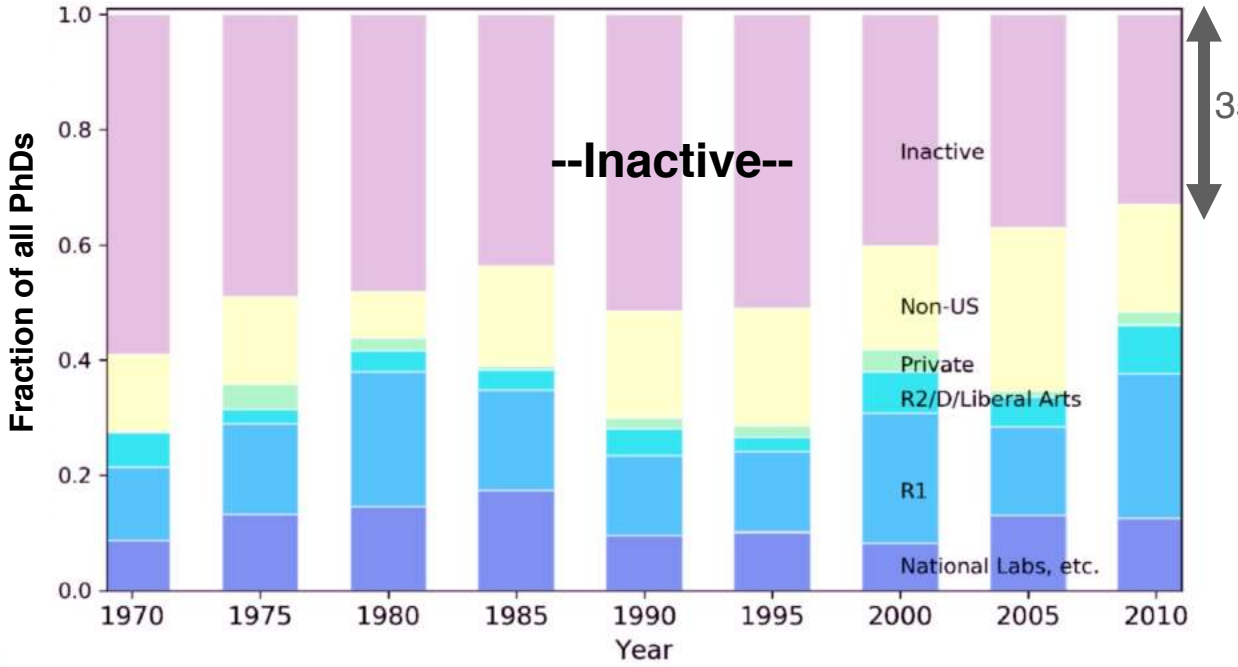
12-Year Cumulative Employment (Data 2000-2012)



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

Decadal Survey (2020): *"There is no evidence of mismatch between the number of PhD- or postdoc-trained astronomers and the broad array of desirable career pathways into the STEM workforce."*

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Kamenetzky (2019): *"The overall nu… per-manent position… ased in the past dec… ~380 per year compar… rs earlier, roughly ke… increase in new PhDs."*

CONCLUDE: NOT GLOOMY, NOT FLUSH. TEMPERED OPTIMISM

permanent jobs in astronomy

Decada… *…here is no evidence of mismatch …en the number of PhD- or postdoc-…ained astronomers and the broad array of desirable career pathways into the STEM workforce."*

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

~1/3 Faculty

~1/3 Research Scientists } 65%

~1/3 Non Astronomy

(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%

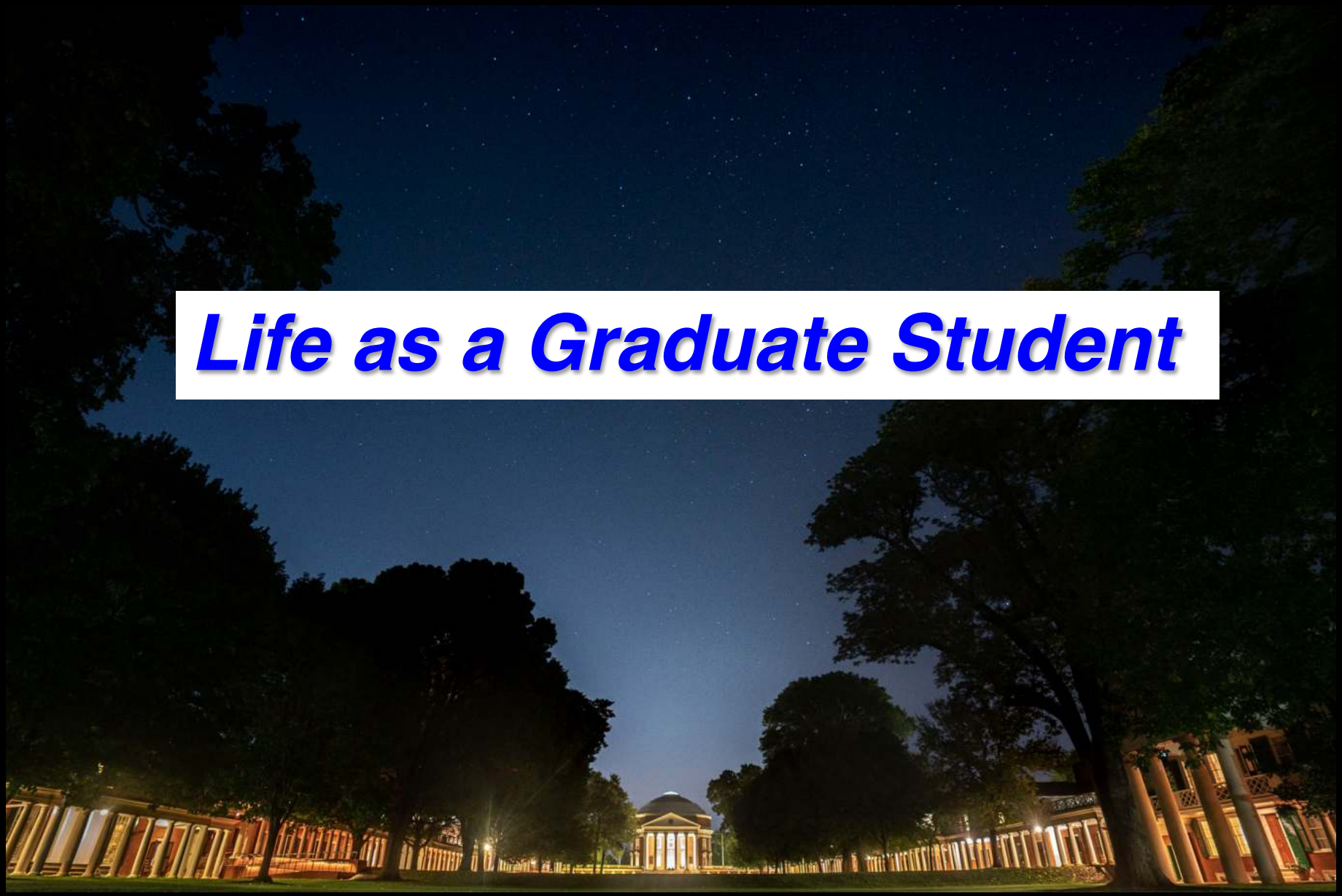
Numbers You Should Know Part 2

Professional effort

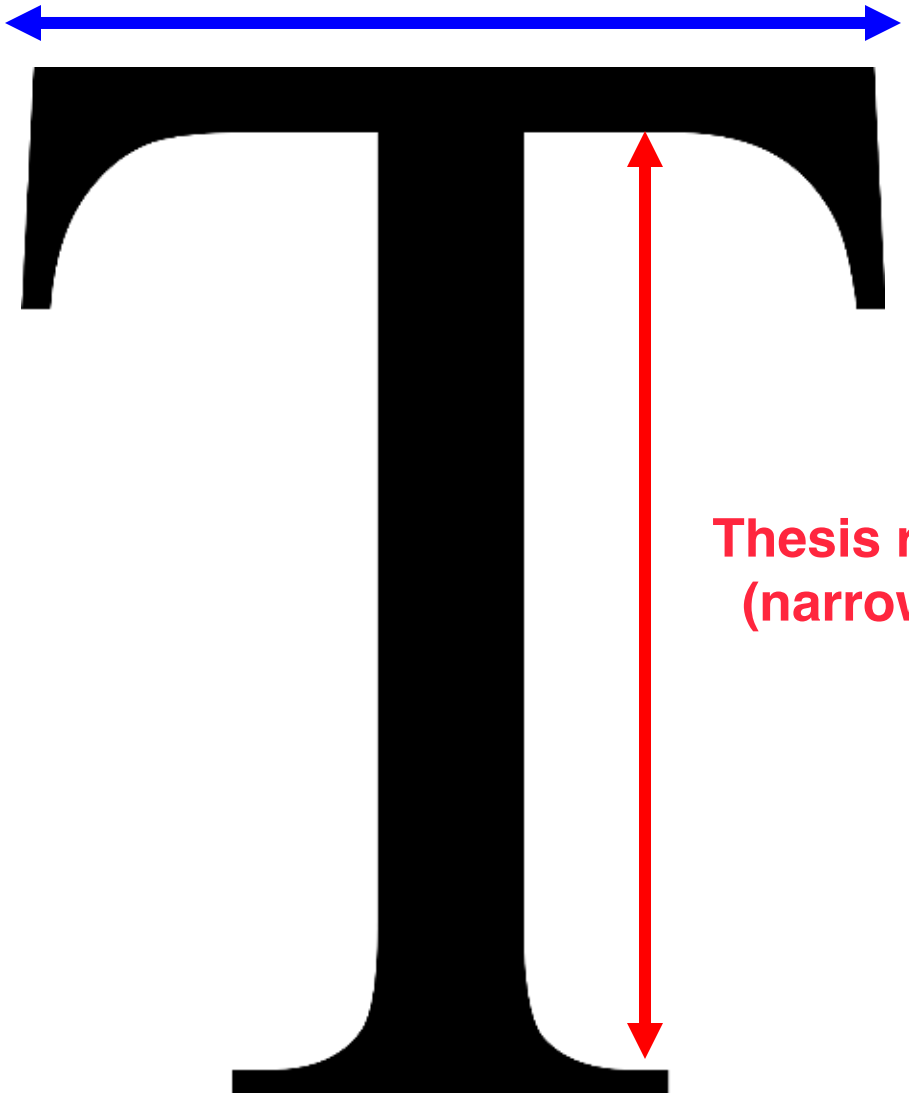
ASTR 8500 Spring 2024 Robert W. O'Connell

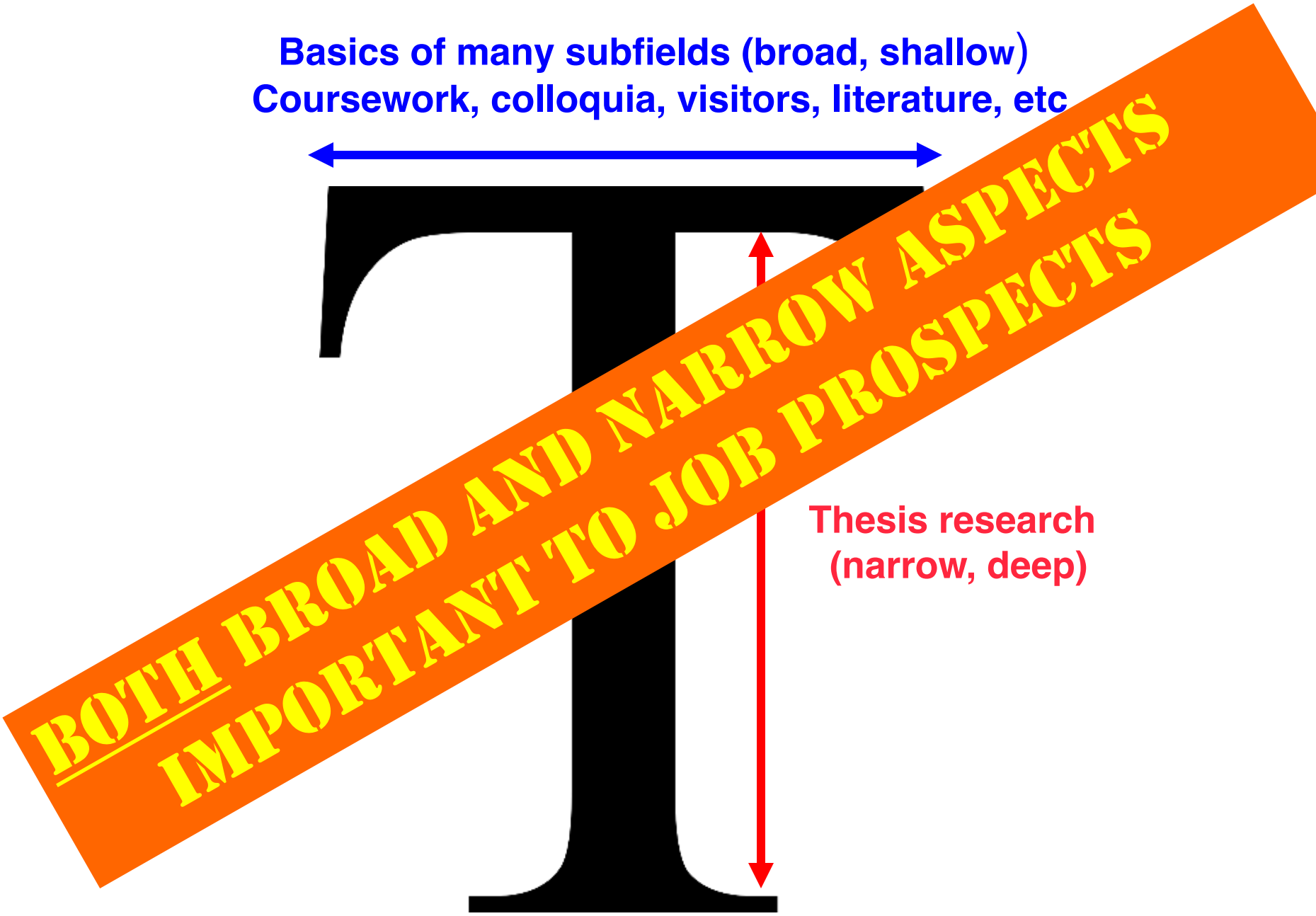
~95(?)%

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




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 HO engagement with a speci erson is ready to make in outions

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
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  - Outreach
- **Research**
  - Personal – undirected
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Tenured profs replace middle management

BENEFITS OF TENURE TO UNIVERSITIES

- Tenure is the central organizing principle of academic program management at good universities.
- Ensures access to a large pool of talented candidate faculty
- 6-year vetting before tenure is awarded selects for people who are productive, committed, and self-motivated.
- Allows academic self-administration by tenured faculty. Very little middle management needed.
- The perk of tenure and absence of middle management reduce salaries and costs to students by at least 30%
- Drastically reduces faculty turnover costs
- Ensures a high quality, stable curriculum from leaders in their fields. Encourages innovation in teaching from experienced teachers.
- Ensures high quality research programs, often taking 5-10 years to develop. Almost by definition, no "Research-1" university can operate without tenure.
- Ensures good corporate memory and loyalty to the institution, critical for good administration
- Ensures a pool of expertise in a wide range of disciplines and specialties, essential for the common good and national security

BENEFITS OF TENURE TO PROFESSORS

- You have the presumption of continued employment as long as you discharge responsibilities effectively
- Academic freedom: you can pursue research of your own choice; you can teach as you wish, within broad limits
- You can be fired for cause, but you cannot be fired...
  - if you're doing a good job...unless the university declares a fiscal emergency; you are insulated to a large extent from administrative incompetence.
  - for administrative convenience
  - for a personality or policy conflict with your superiors
  - for what you think or write or say, in or out of class
- You don't have to worry that specialization in research will make you unemployable in your mid- to late-career.

Sadly, in 2024, academic freedom is under assault from both ends of the political spectrum.

The New York Times

The Fight Over Academic Freedom

Amid spiraling campus speech debates, many professors are rallying in defense of a bedrock principle. But can they agree on just what it means?

Share full article

A gate at Harvard University showing the school's motto, "Veritas," or "Truth." Adam Glanzman for The New York Times

By Jennifer Schuessler

Feb. 16, 2024

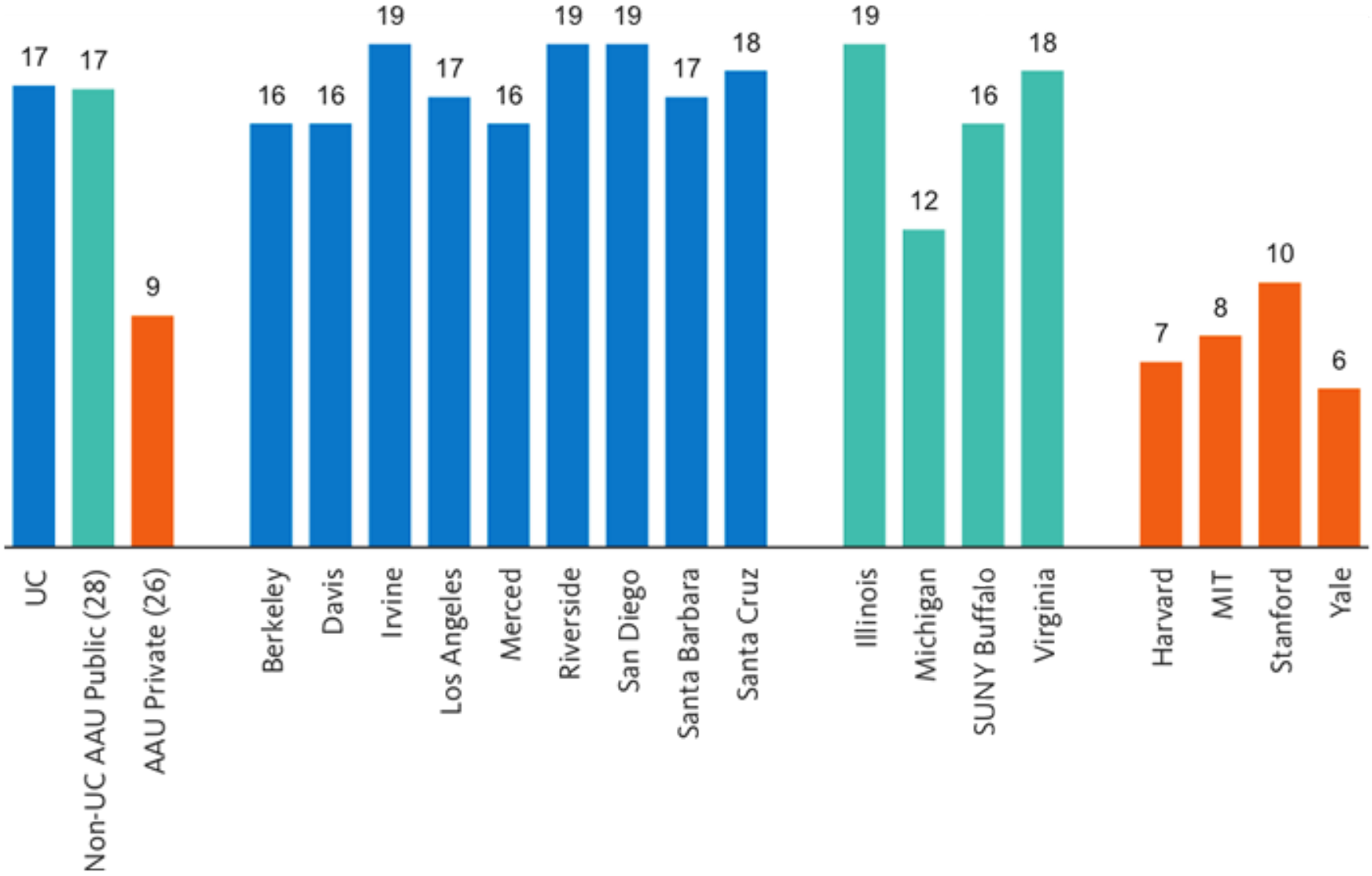

BENEFITS OF TENURE TO PROFESSORS
o You have the presumption of continued empl ng as you discharge responsibilities effectively
o Academic freedom: you can pursue choice; you can teach as you wish, wit
o You can be fired for ca fired...
o if you're doing the university declares a fiscal em ated to a large extent from adminis
o fo enience
or policy conflict with your superiors
think or write or say, in or out of class
have to worry that specialization in research make you unemployable in your mid- to late-career.
OPTIONAL TOPIC: "WHAT GOOD IS TENURE? "

~90-200

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

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

Student/Faculty Ratios




...and here they are!

~7:1

= 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

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

OPTIONAL TOPIC: "HOW TO GIVE A BAD TALK"

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

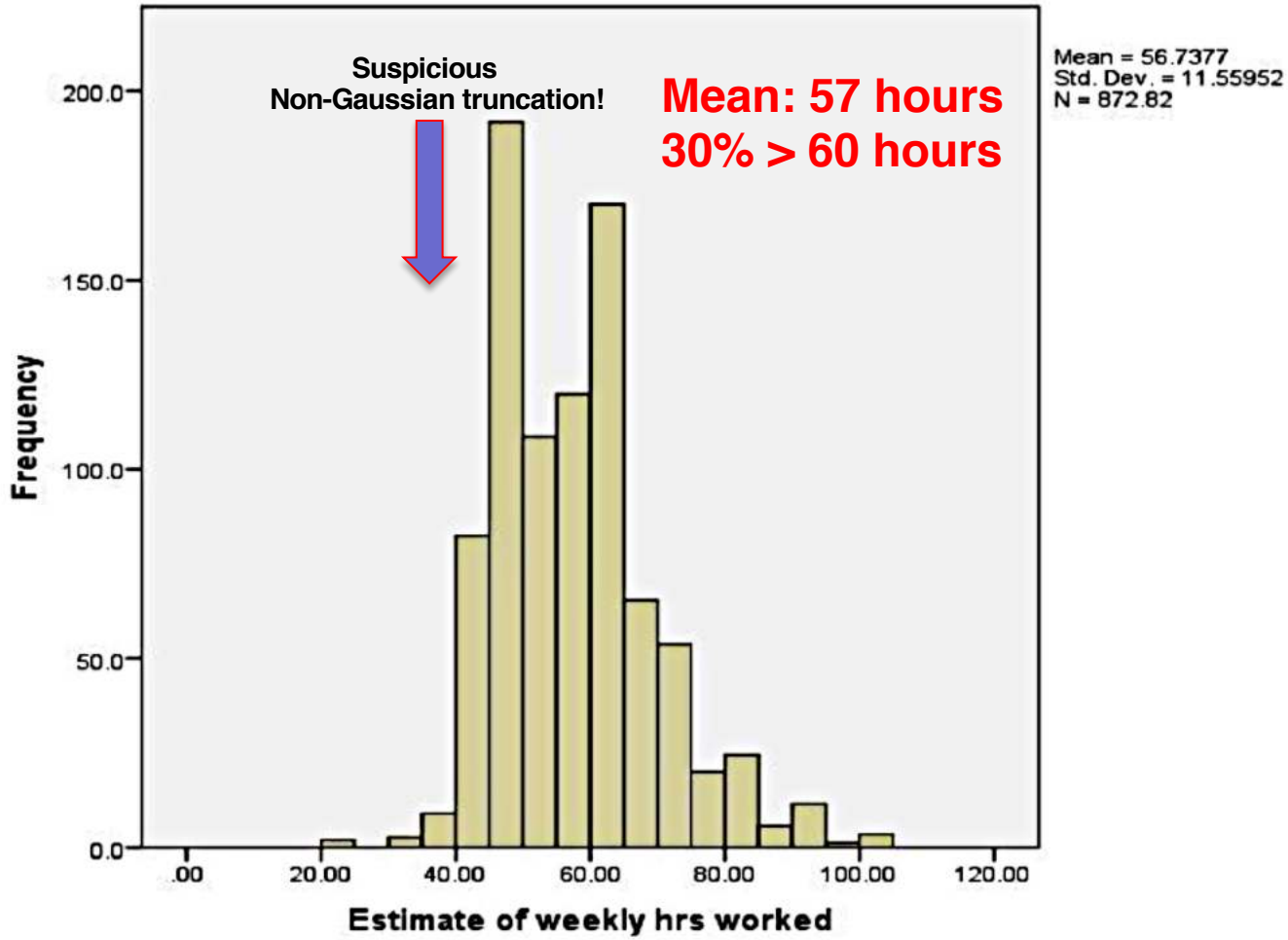

MUST PLAN FOR HEAVY DEMANDS
OF TEACHING ON YOUR TIME

~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.

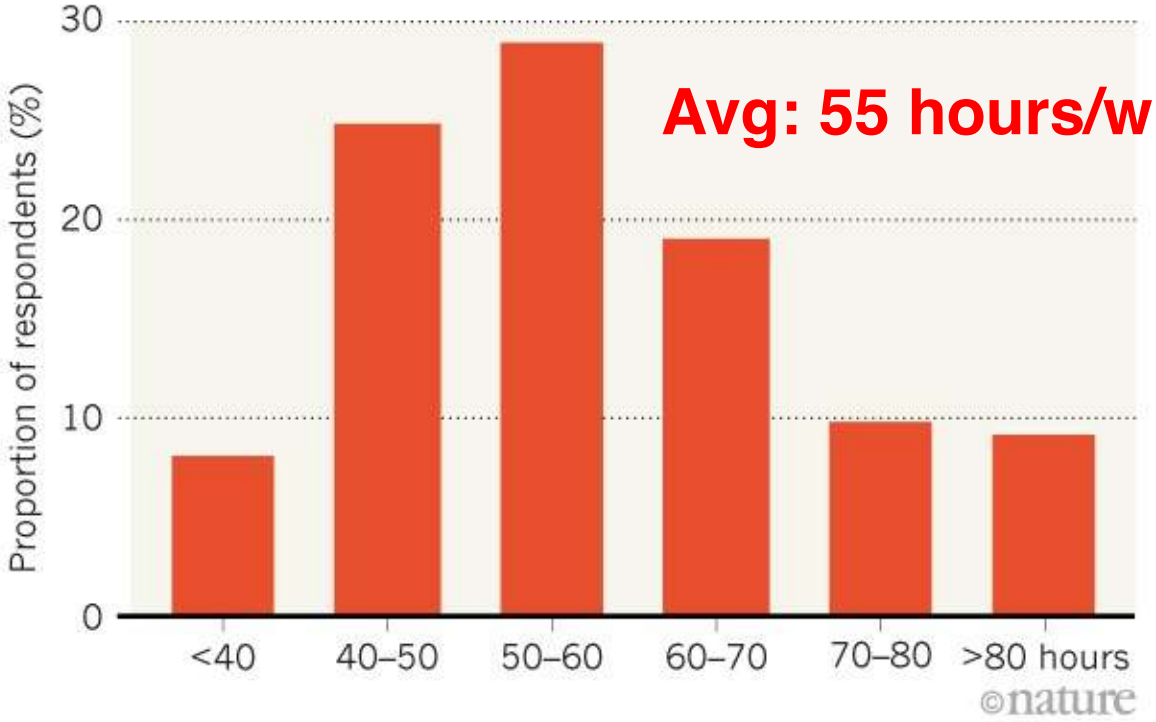


Scientist Survey: Hours Worked (Nature)

LONG HOURS

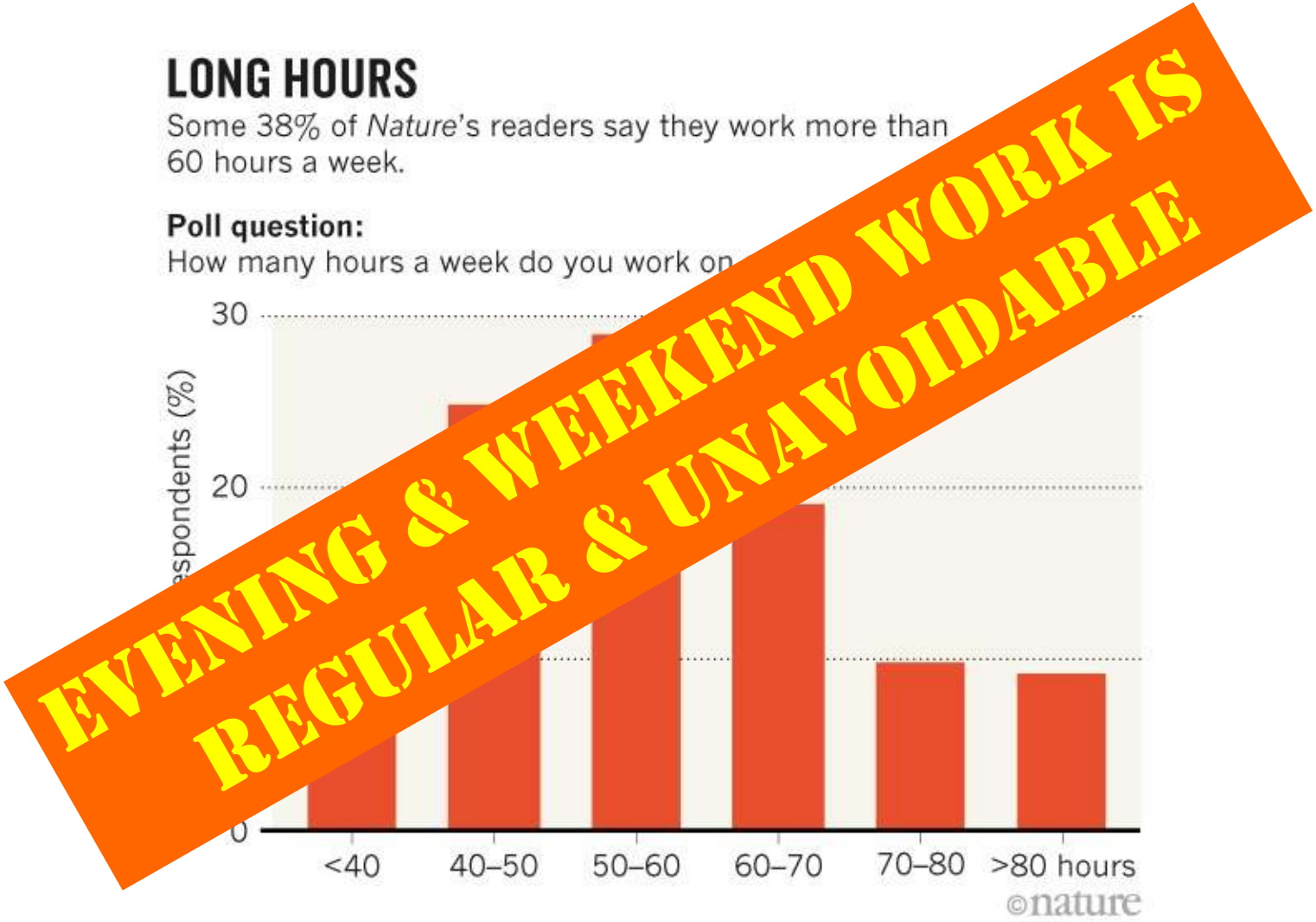
Some 38% of *Nature*'s readers say they work more than 60 hours a week.

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



Avg: 55 hours/wk ✓

Scientist Survey: Hours Worked (Nature)



Work-Life Balance?
Can be good, but unlikely 9-5x5

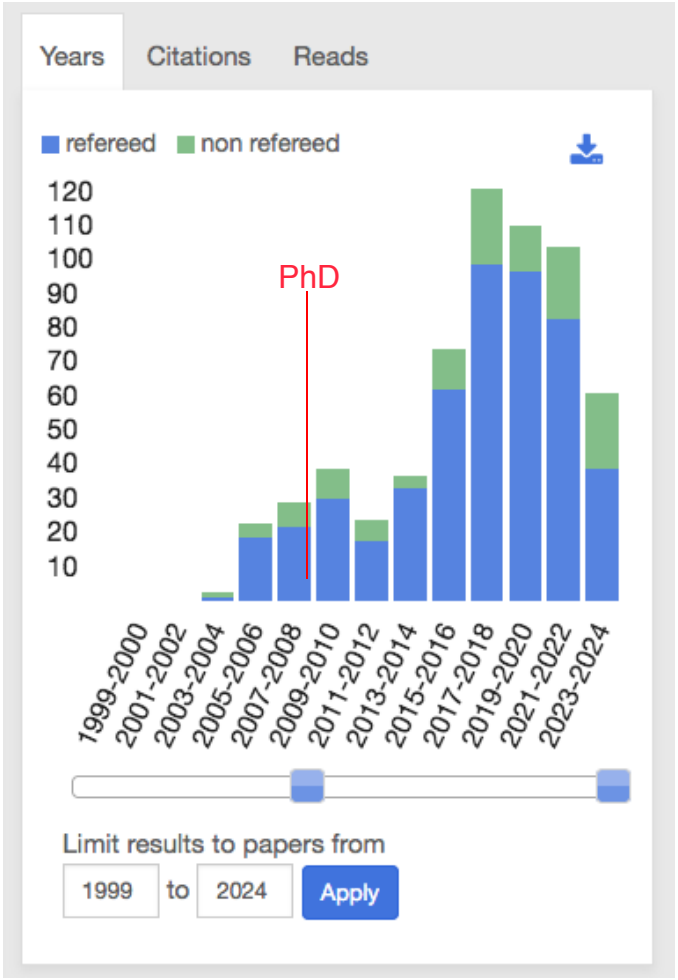
Work-Life Balance?
Can be good, but unlikely 9-5x5

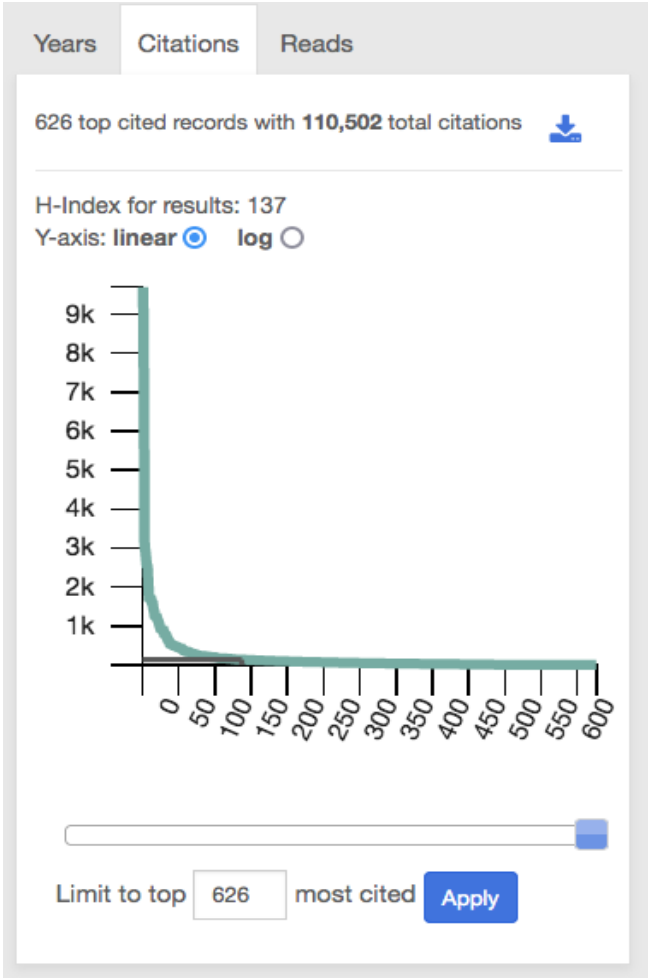
Most observing is done at night
and at remote sites.

Work-Life Balance?
Can be good, but unlikely 9-5x5

Important deadlines are set by others and are often inflexible.

Work-Life Balance?
Can be good, but unlikely 9-5x5





Expected pace of research is set by most productive outliers

Work-Life Balance?
Can be good, but unlikely 9-5x5

Astronomy is a global enterprise. Your colleagues can be in any of the 24 time zones.

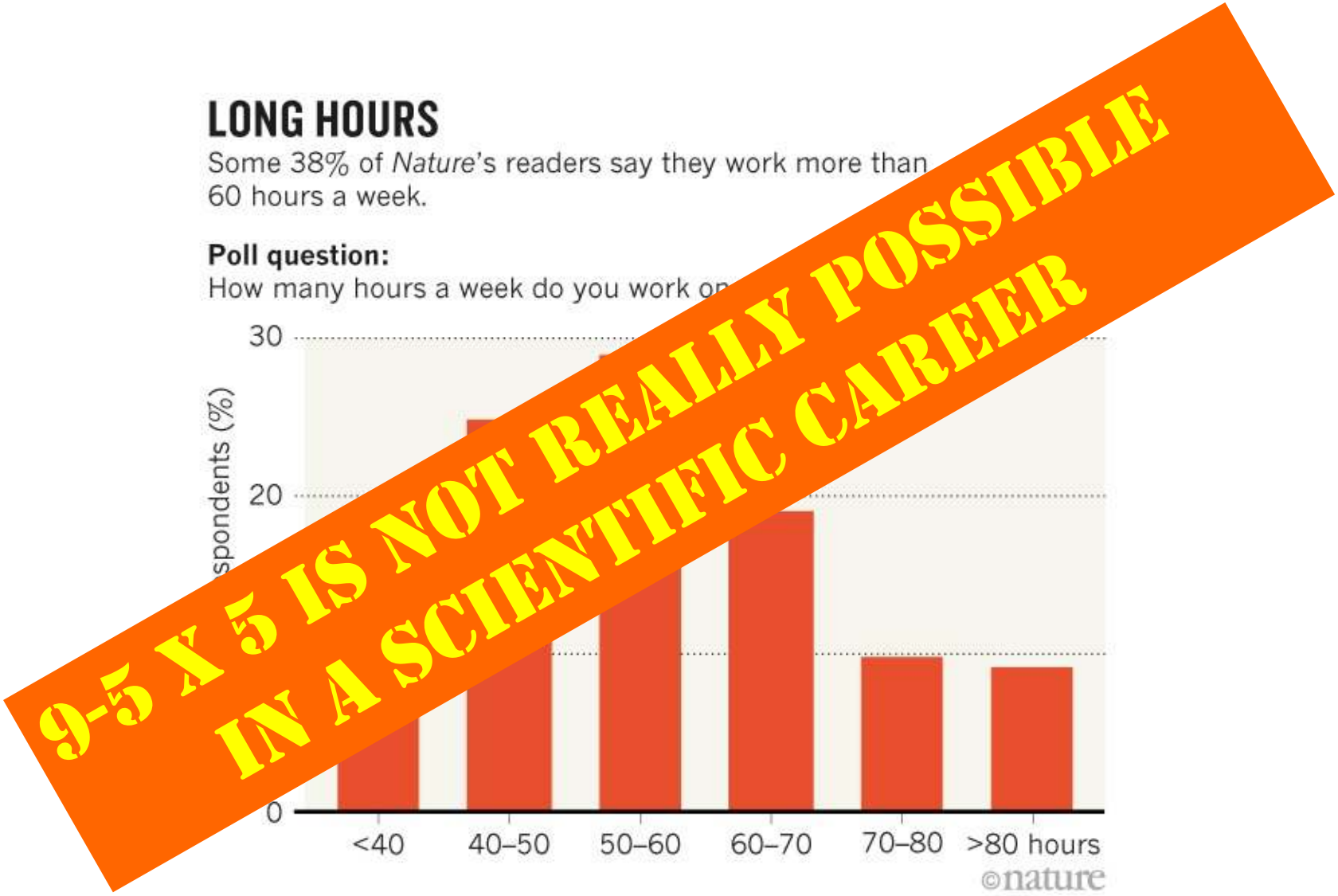
Work-Life Balance?
Can be good, but unlikely 9-5x5

NASA mission schedules constrained by budget, technology development, person-power, orbital physics -- not convenience of participants

Work-Life Balance?
Can be good, but unlikely 9-5x5

You will have many opportunities to travel for "work," often to nice places. Take advantage of this hidden perk.

Scientist Survey: Hours Worked (Nature)



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  - Disciplinar , planning, meetings, advocacy
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TIME MANAGEMENT IS AN ESSENTIAL SKILL

Job Profile of a Faculty Member

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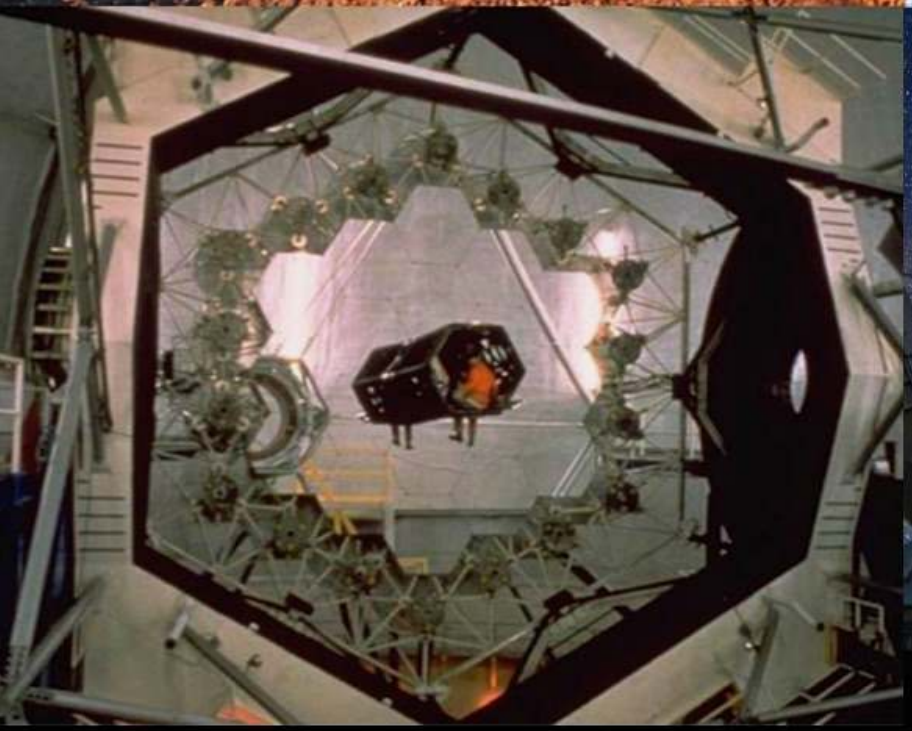
OPTIONAL TOPIC: "MANAGING YOUR TIME"

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
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Job Profile of a Research Scientist

- Main occupational hazard of a research scientist?

Job Profile of a Research Scientist

- Main occupational hazard of a research scientist?

Meetings

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

~1/3 Faculty

~1/3 Research Scientists

65%

~1/3 Non Astronomy

(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

"Non-Dedicated Astronom

Jobs drawing on general training i

Examples:

- Space science/applica s, commercial)
- High-end compu
- Computati s, neurology)
- Com crowave, fiber/laser)
- sors, imaging, optics)

OPTIONAL TOPIC: EMPLOYMENT OUTSIDE ASTRONOMY

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%
>5	3%	39%
Max # to date	54	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 !

The Astrophysical Journal Letters, 848:L12 (59pp), 2017 October 20 https://doi.org/10.3847/2041-8213/aa91c9

OPEN ACCESS

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
(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 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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GROUPS, not people

B. P. Abbott[1], R. Abbott[1], T. D. Abbott[2], F. Acernese[3,4], K. Ackley[5,6], C. Adams[7], T. Adams[8], P. Addesso[9], R. X. Adhikari[1], V. B. Adya[10], C. Affeldt[10], M. Afrough[11], B. Agarwal[12], M. Agathos[13], K. Agatsuma[14], N. Aggarwal[15], O. D. Aguiar[16], L. Aiello[17,18], A. Ain[19], P. Ajith[20], B. Allen[10,21,22], G. Allen[12], A. Allocca[23,24], P. A. Altin[25], A. Amato[26], A. Ananyeva[1], S. B. Anderson[1], W. G. Anderson[21], S. V. Angelova[27], S. Antier[28], S. Appert[1], K. Arai[1], M. C. Araya[1], J. S. Areeda[29], N. Arnaud[28,30], K. G. Arun[31], S. Ascenzi[32,33], G. Ashton[10], M. Ast[34], S. M. Aston[7], P. Astone[35], D. V. Atallah[36], P. Aufmuth[22], C. Aulbert[10], K. AultONeal[37], C. Austin[2], A. Avila-Alvarez[29], S. Babak[38], P. Bacon[39], M. K. M. Bader[14], S. Bae[40], P. T. Baker[41], F. Baldaccini[42,43], G. Ballardin[30], S. W. Ballmer[44], S. Banagiri[45], J. C. Barayoga[1], S. E. Barclay[46], B. C. Barish[1], D. Barker[47], K. Barkett[48], F. Barone[3,4], B. Barr[46], L. Barsotti[15], M. Barsuglia[39], D. Barta[49], S. D. Barthelmy[50], J. Bartlett[47], I. Bartos[51,5], R. Bassiri[52], A. Basti[23,24], J. C. Batch[47], M. Bawaj[53,43], J. C. Bayley[46], M. Bazzan[54,55], B. Bécsy[56], C. Beer[10], M. Bejger[57], I. Belahcene[28], A. S. Bell[46], B. K. Berger[1], G. Bergmann[10], J. J. Bero[58], C. P. L. Berry[59], D. Bersanetti[60], A. Bertolini[14], J. Betzwieser[7], S. Bhagwat[44], R. Bhandare[61], I. A. Bilenko[62], G. Billingsley[1], C. R. Billman[5], J. Birch[7], R. Birney[63], O. Birnholtz[10], S. Biscans[1,15], S. Biscoveanu[64,6], A. Bisht[22], M. Bitossi[30,24], C. Biwer[44], M. A. Bizouard[28], J. K. Blackburn[1], J. Blackman[48], C. D. Blair[1,65], D. G. Blair[65], R. M. Blair[47], S. Bloemen[66], O. Bock[10], N. Bode[10], M. Boer[67], G. Bogaert[67], A. Bohe[38], F. Bondu[68], E. Bonilla[52], R. Bonnand[8], B. A. Boom[14], R. Bork[1], V. Boschi[30,24], S. Bose[69,19], K. Bossie[7], Y. Bouffanais[39], A. Bozzi[30], C. Bradaschia[24], P. R. Brady[21], M. Branchesi[17,18], J. E. Brau[70], T. Briant[71], A. Brillet[67], M. Brinkmann[10], V. Brisson[28], P. Brockill[21], J. E. Broida[72], A. F. Brooks[1],

- 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

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- 3611 authors
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- 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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Multimessenger search for sources of gravitational waves and high-energy neutrinos: Initial results for LIGO-Virgo and IceCube

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