

# Reproducibility and Open Science

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Dr. Rachael Ainsworth  
Community Manager  
Software Sustainability Institute, University of Manchester

 @rachaelevelyn

 @rainsworth

 [10.6084/m9.figshare.10255727](https://doi.org/10.6084/m9.figshare.10255727)

# Outline

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- About me and my Open Science journey
- Reproducibility and research culture
- Open Science/Research/Scholarship
- Barriers to open research
- Why research openly?
- How to open up your research workflow
- Open Science in Astronomy & a case study
- Takeaways



# About me and my Open Science journey

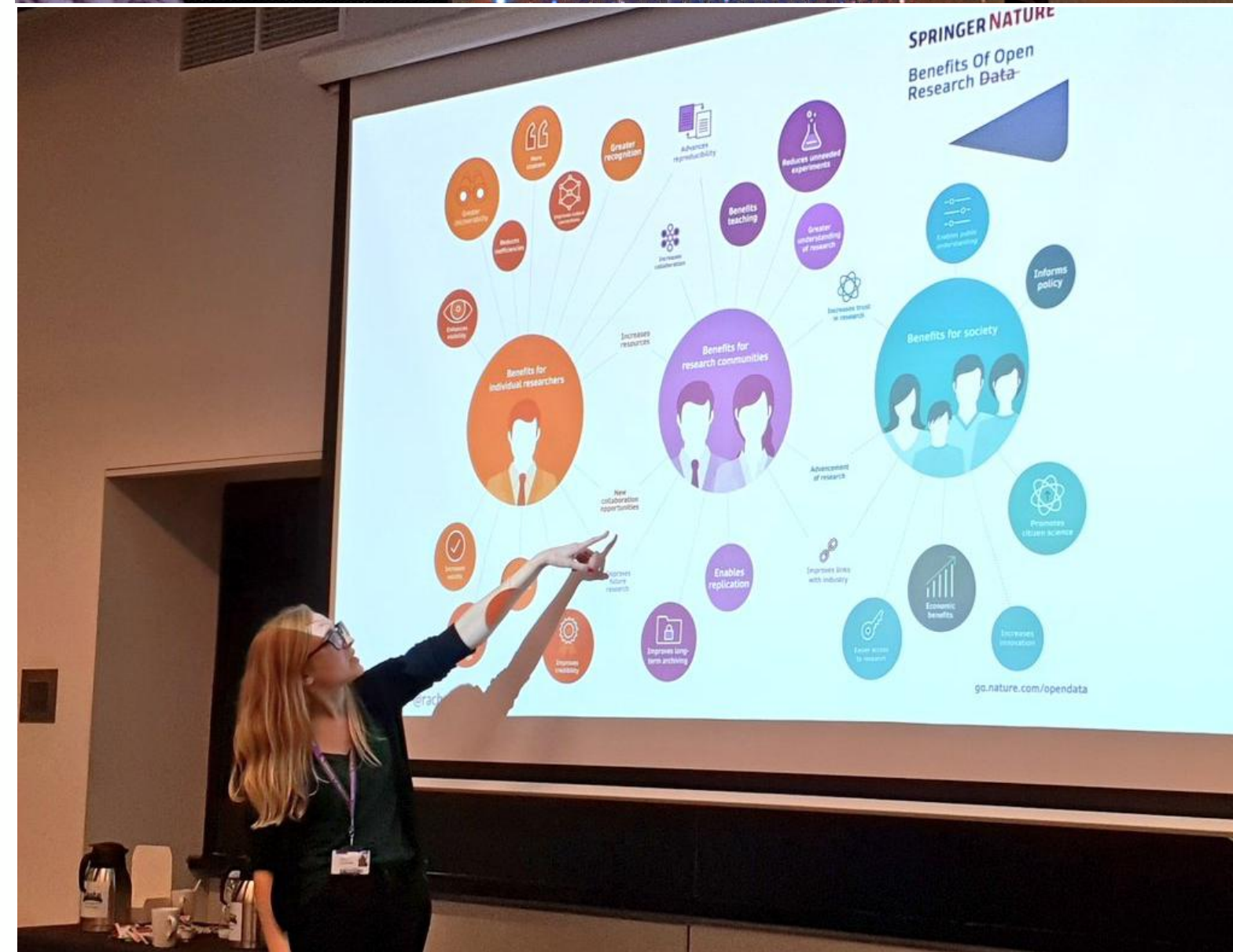


# About me

- Community Manager for the Software Sustainability Institute at the University of Manchester
- Research background in Astrophysics
- Passionate about openness, transparency, reproducibility, wellbeing and inclusion in STEM
- Currently a cartoon in the UK's National Science and Media Museum Hello Universe exhibition
- Organise the Manchester women in data meetup group

HER+**Data** MCR

[meetup.com/HER-Data-MCR](https://meetup.com/HER-Data-MCR)





# My career path and Open Science journey

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BSc Physics

University of Tennessee

- Interned at NASA's JPL

2005-  
2010





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2010-  
2014

PhD Astrophysics

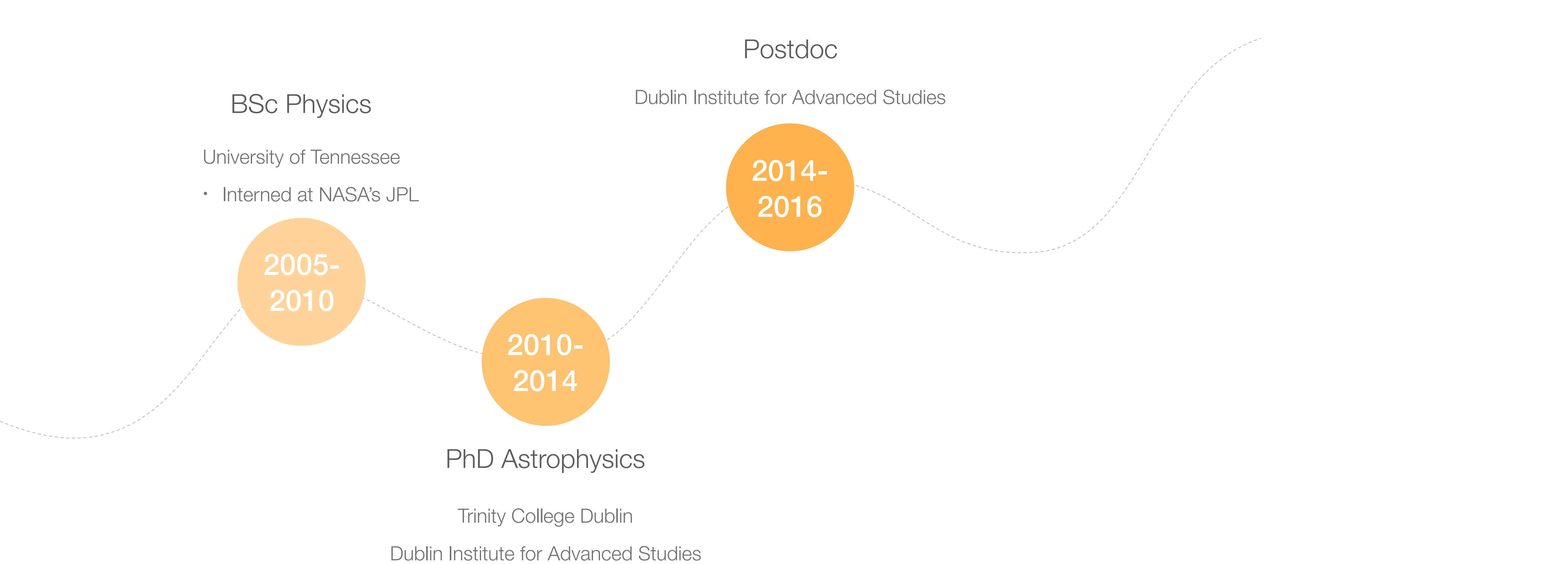
Trinity College Dublin

Dublin Institute for Advanced Studies



# My career path and Open Science journey

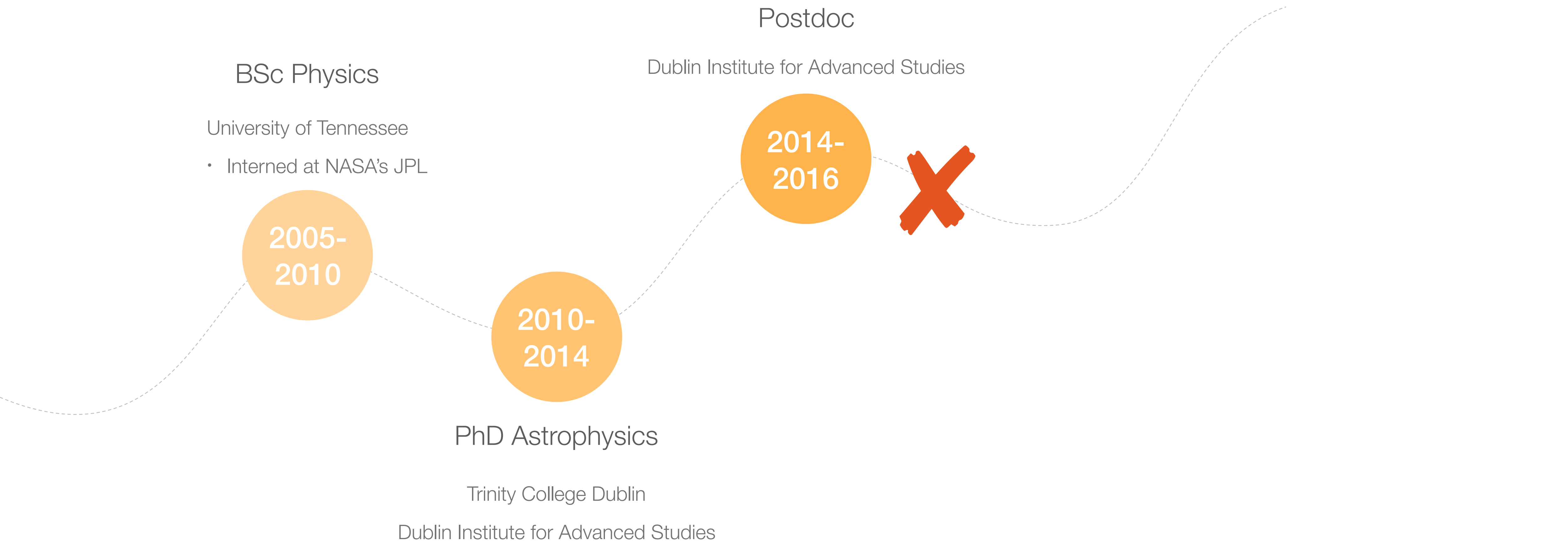
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# My career path and Open Science journey

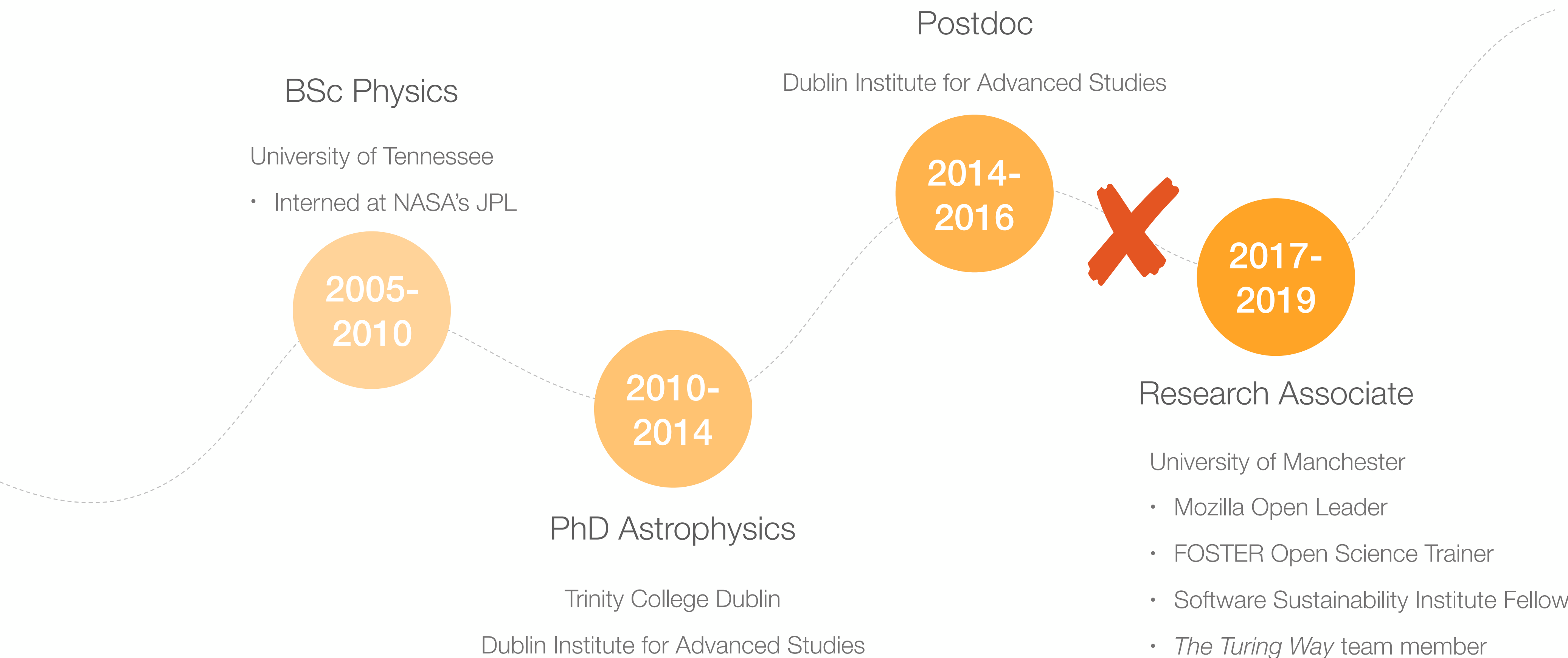
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# My career path and Open Science journey

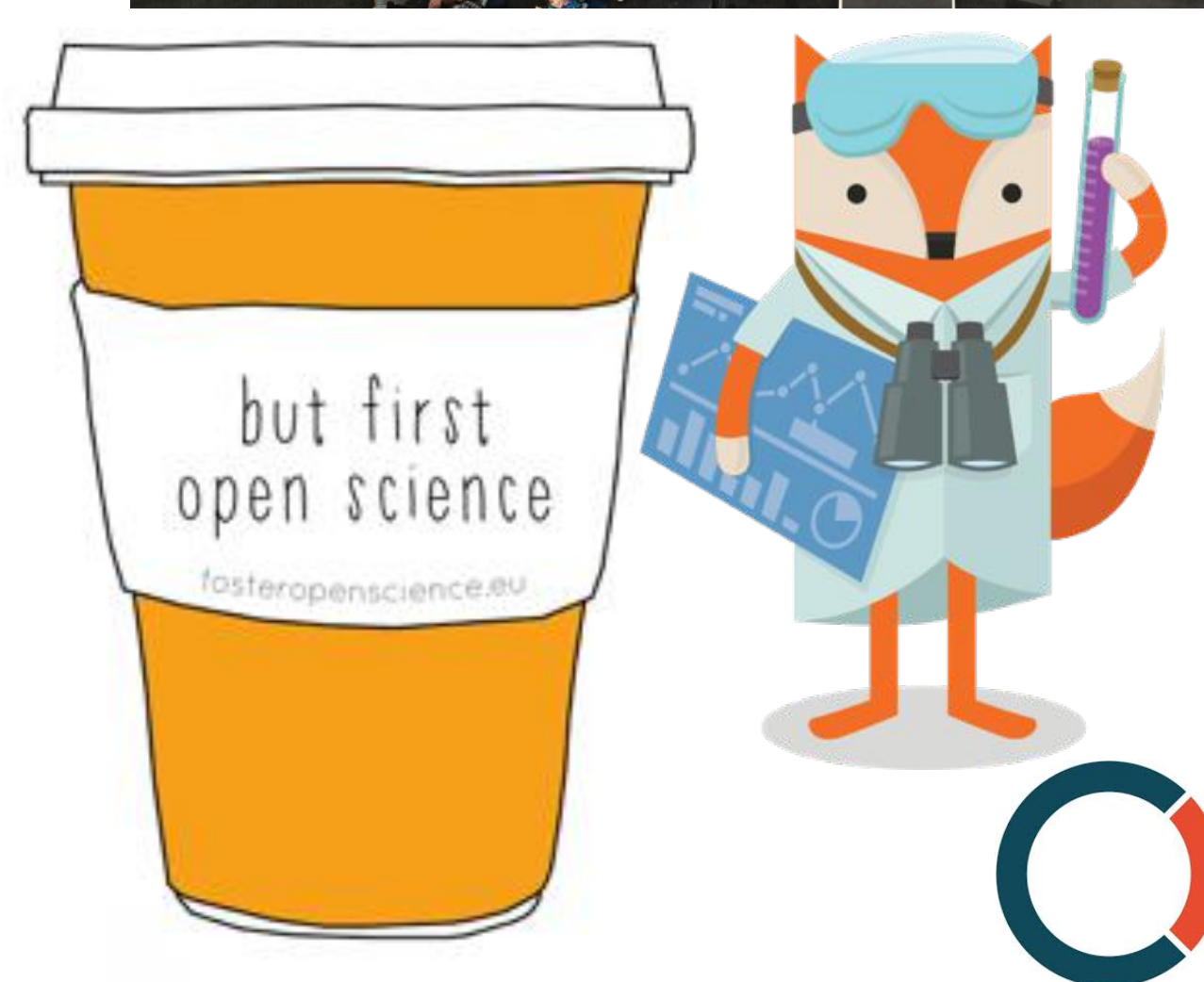
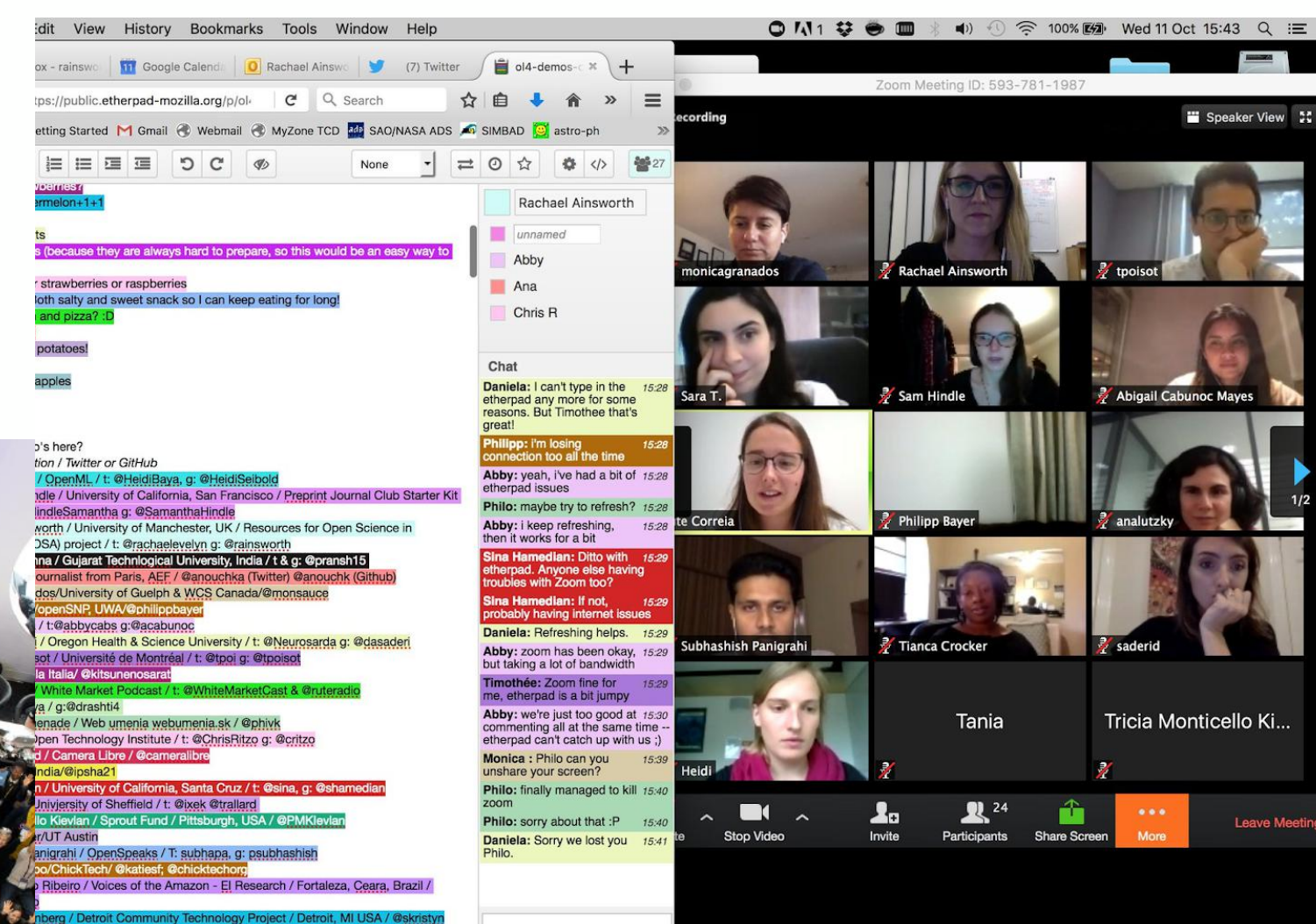
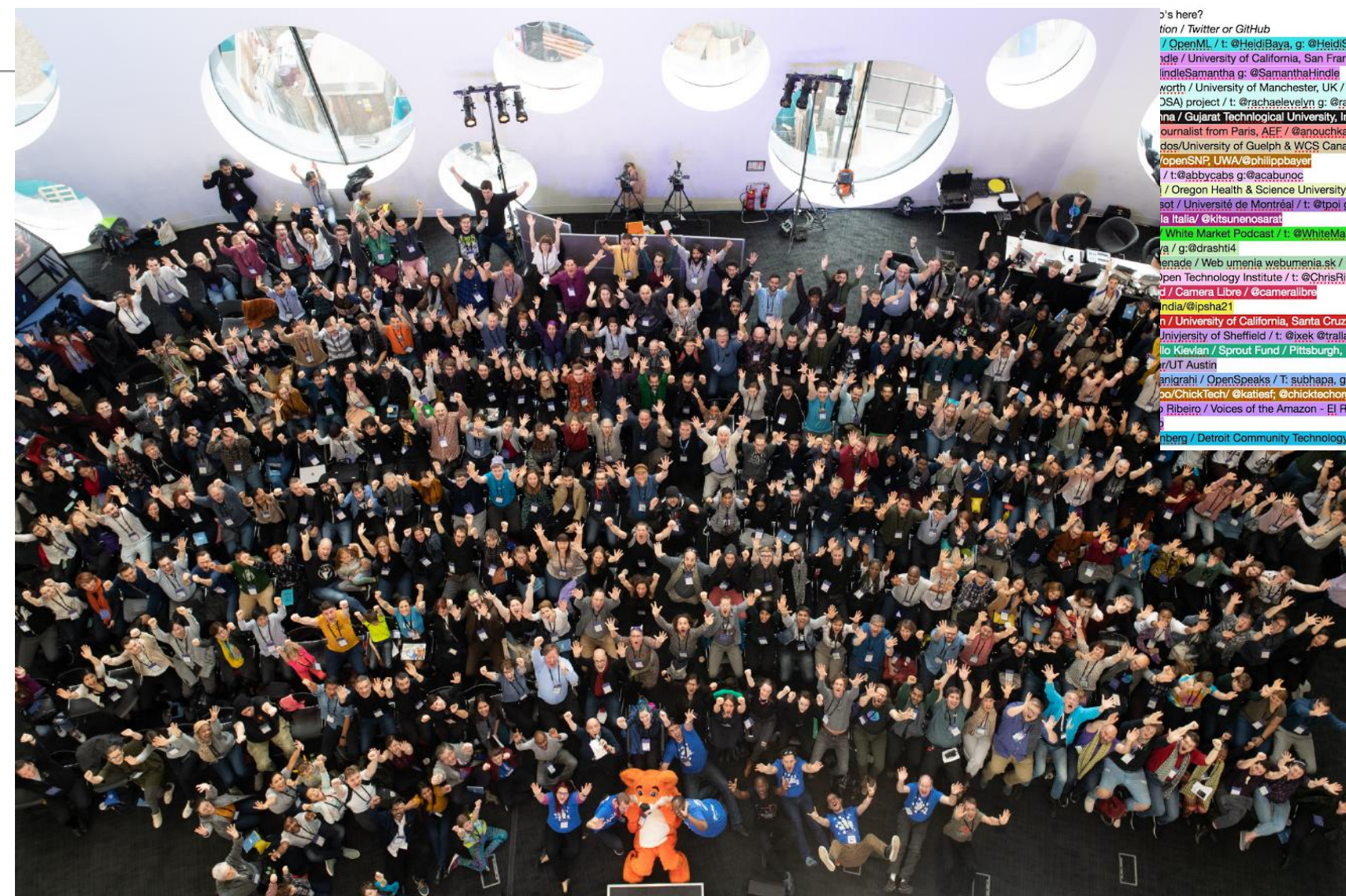
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# Open Science Advocacy

- Mozilla Open Leaders
  - Round 4 Project Lead
  - Round 5 Mentor, Cohort Host
- Mozilla Festival 2017, 2018
- OpenCon 2017
- FOSTER Open Science Trainer Bootcamp
- Mozilla Global Sprint 2018
- Speaker at Open Science events
- Software Sustainability Institute Fellow 2019
- *The Turing Way* team member
- Open Science Fair 2017, 2019



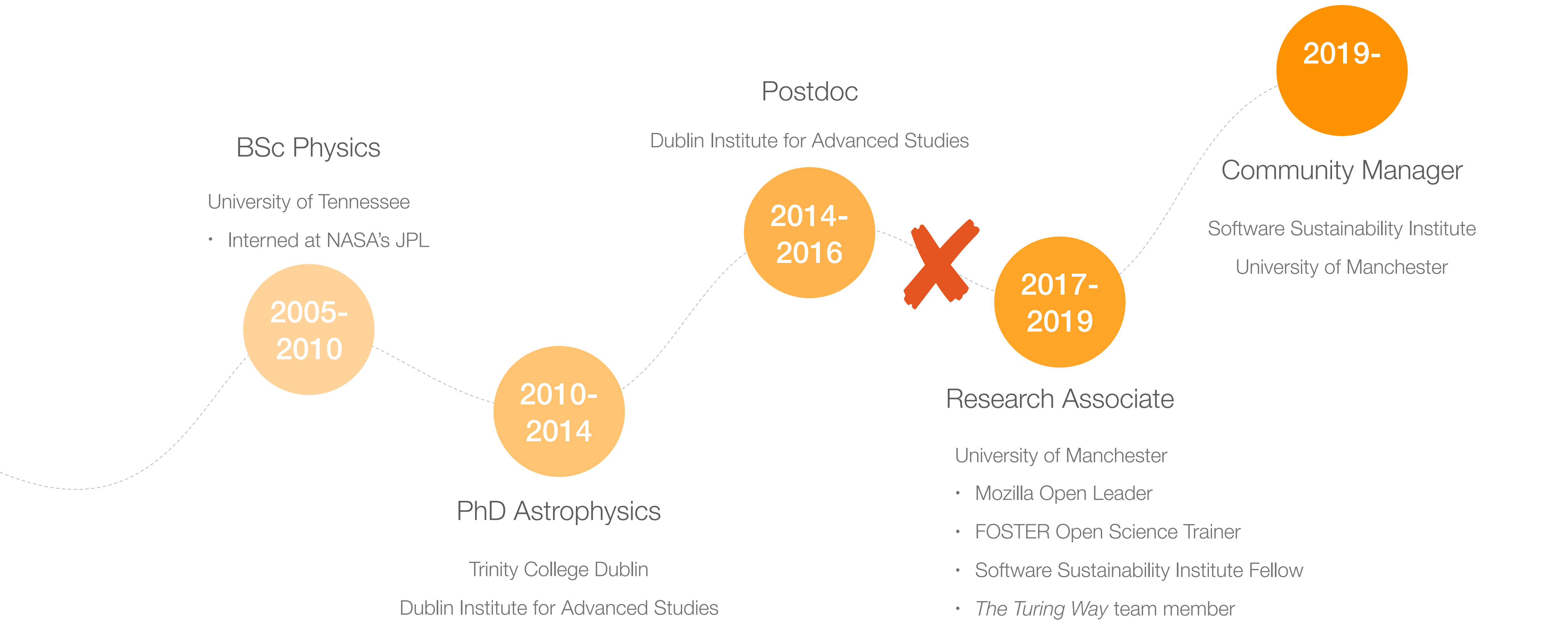




## Research Culture is Broken; Open Science can [help] Fix It

<https://youtu.be/c-bemNZ-lqA>

# My career path and Open Science journey





# Reproducibility and research culture

		Data	
		Same	Different
Analysis	Same	Reproducible	Replicable
	Different	Robust	Generalisable

Whitaker (2018) <https://doi.org/10.6084/m9.figshare.7140050.v2>

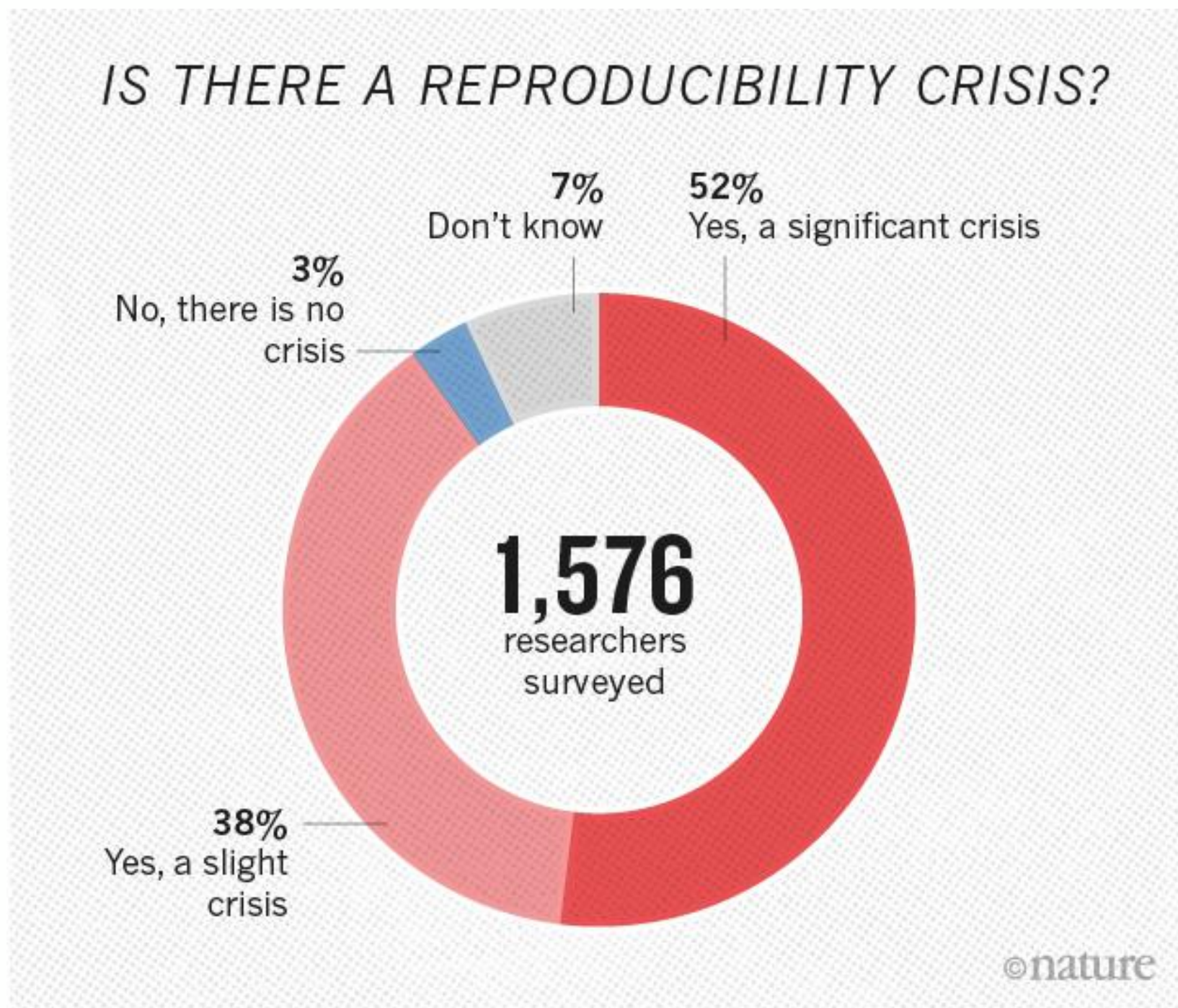


# 1,500 scientists lift the lid on reproducibility

Survey sheds light on the 'crisis' rocking research.

Monya Baker

25 May 2016 | Corrected: 28 July 2016



Baker (2016) <https://doi.org/10.1038/533452a>

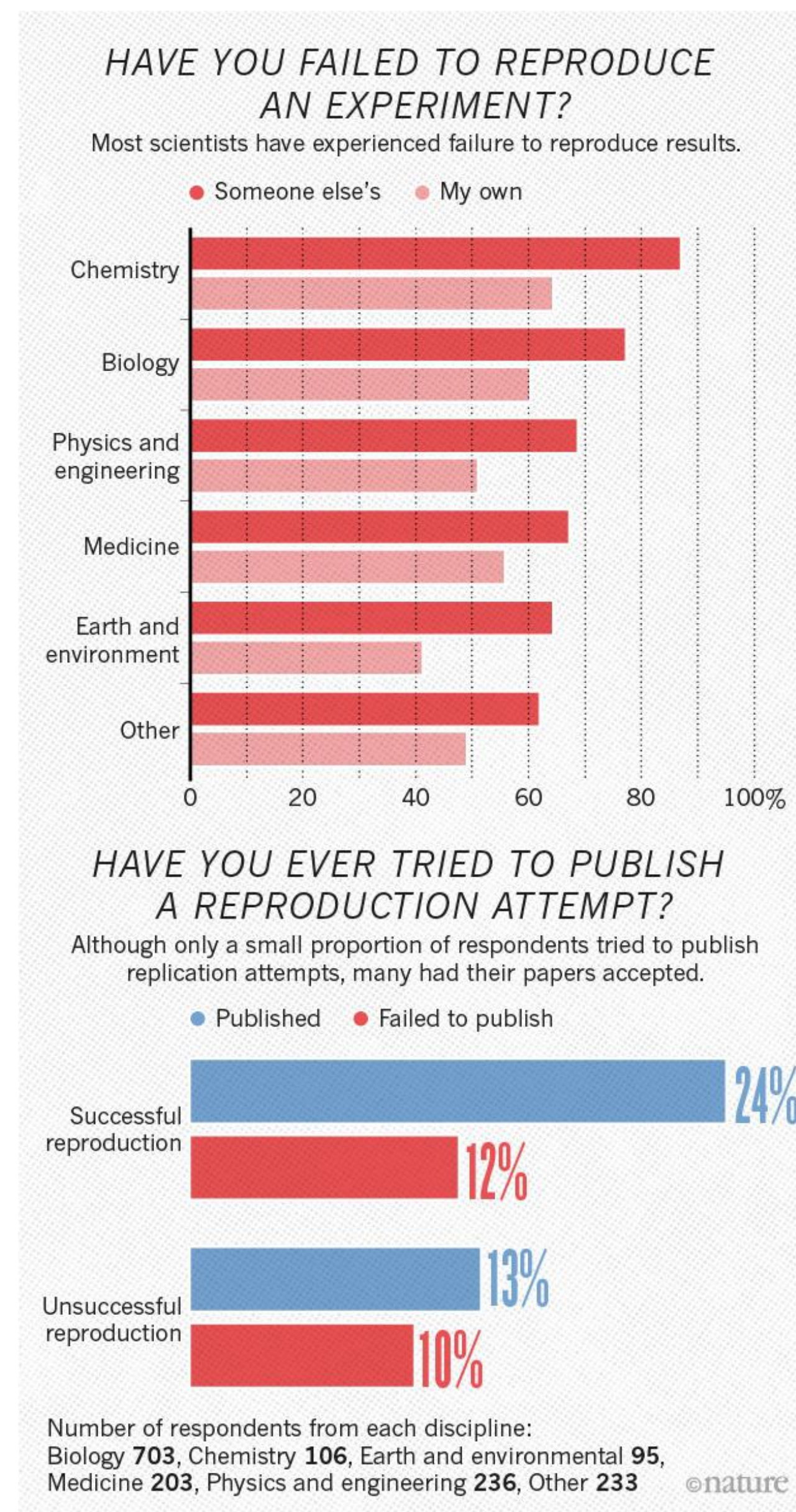
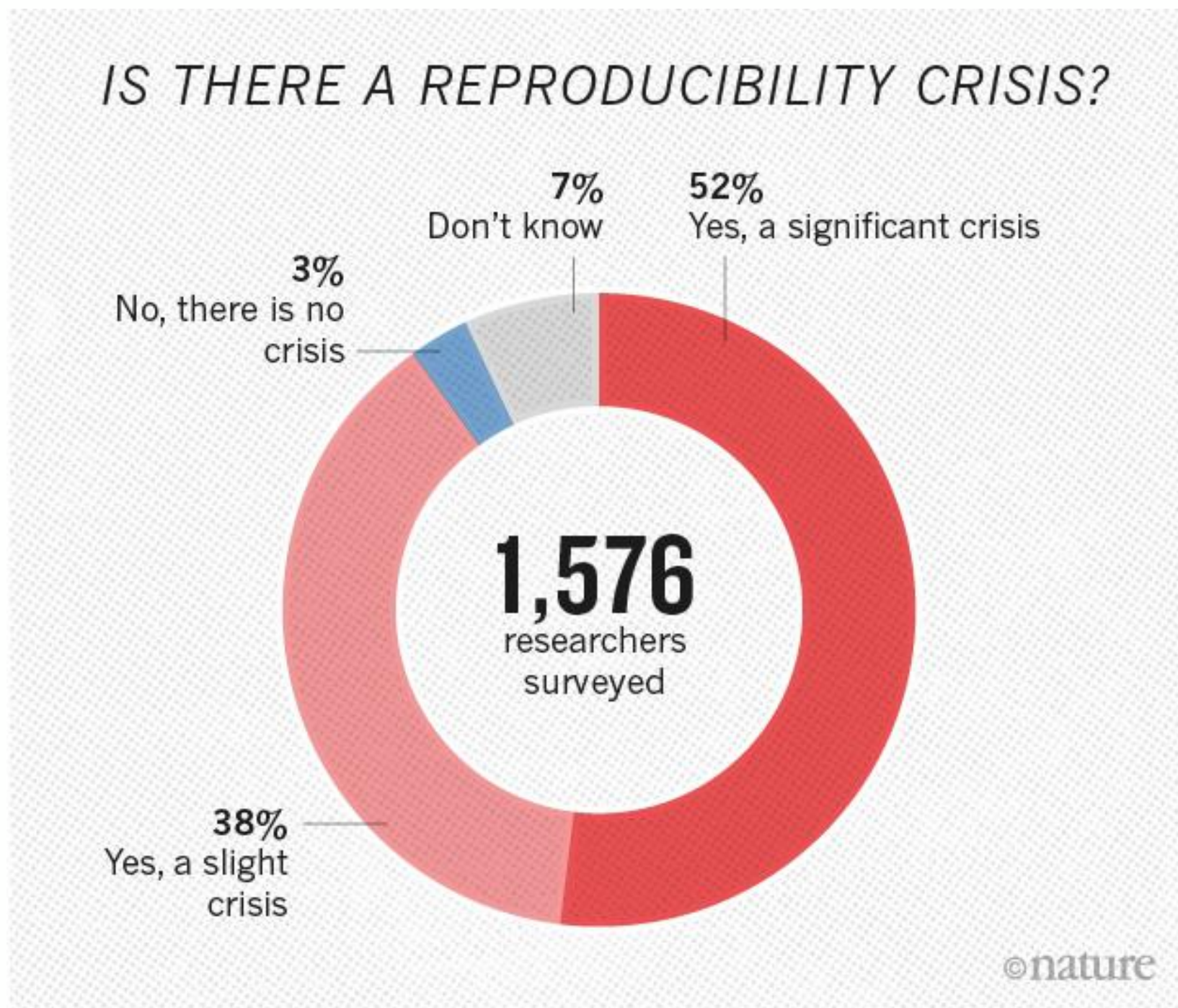


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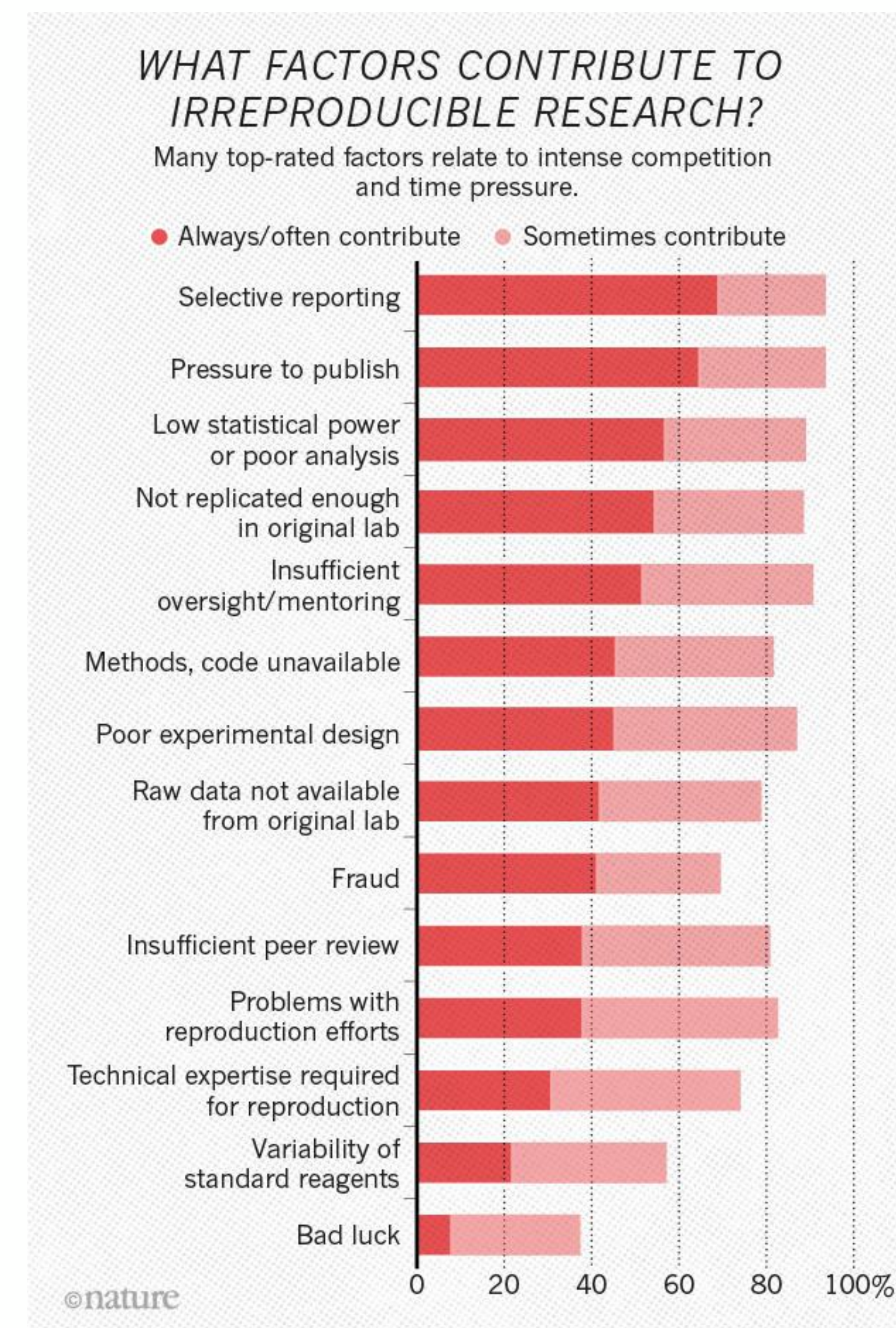
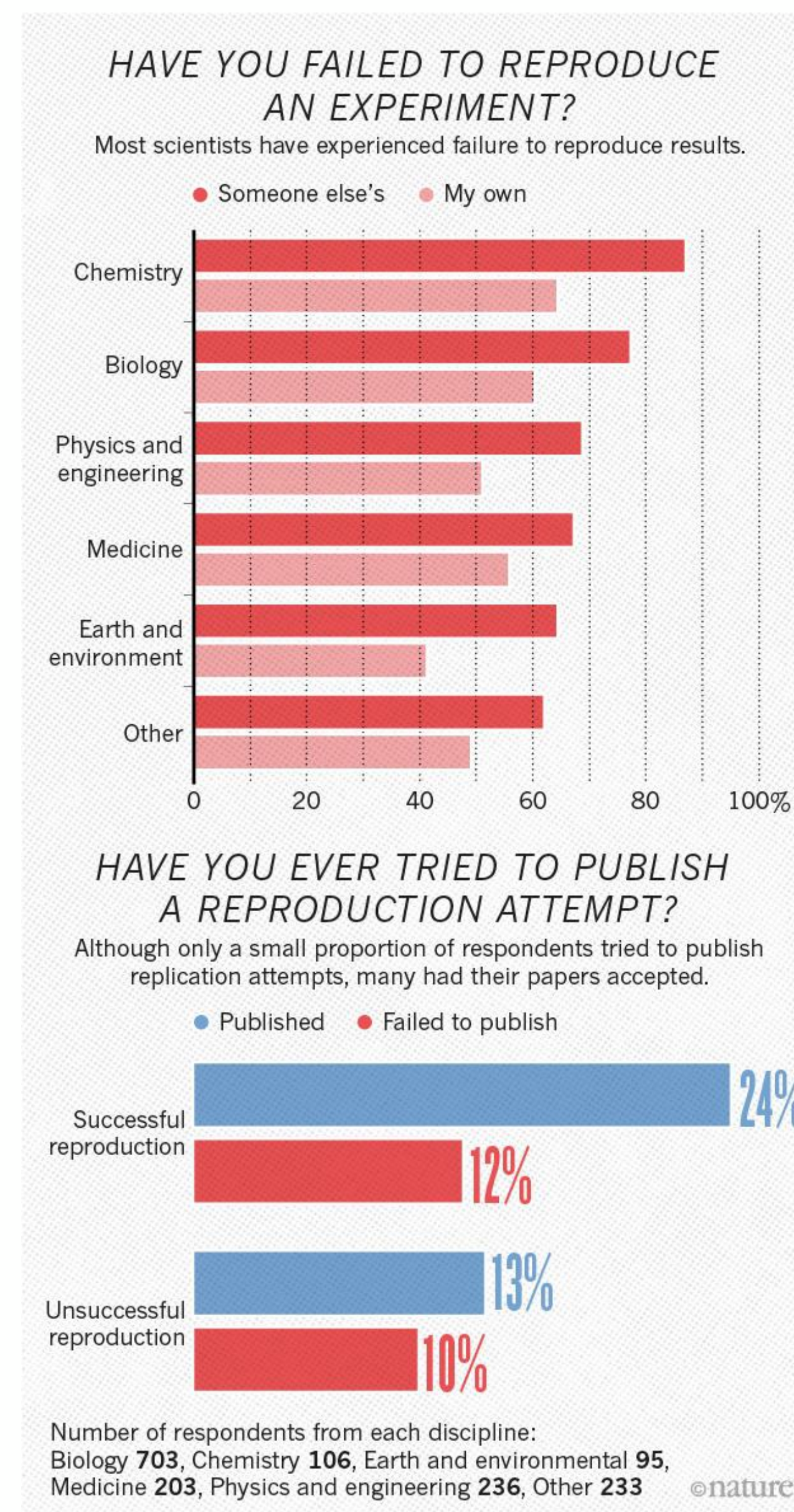
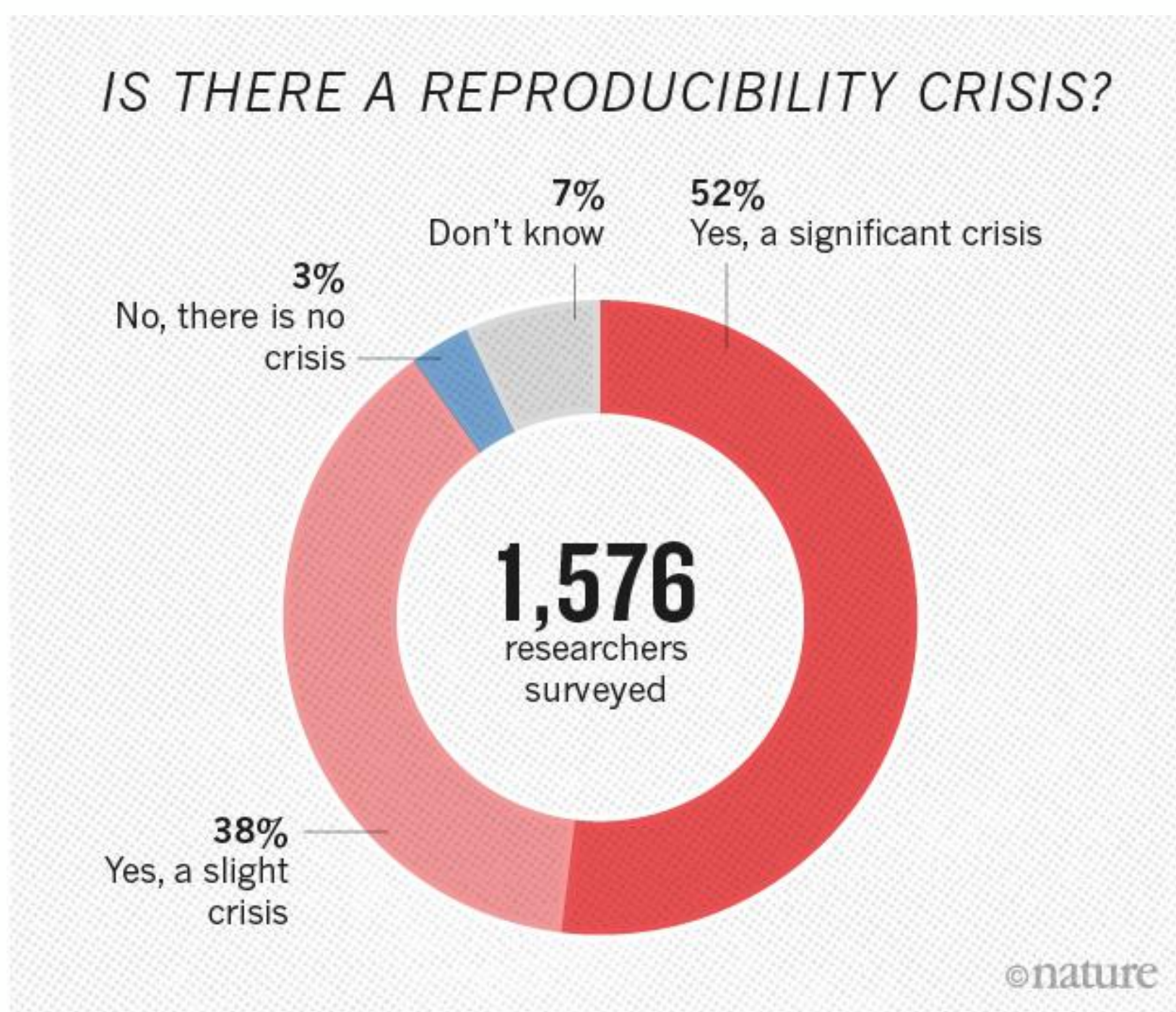


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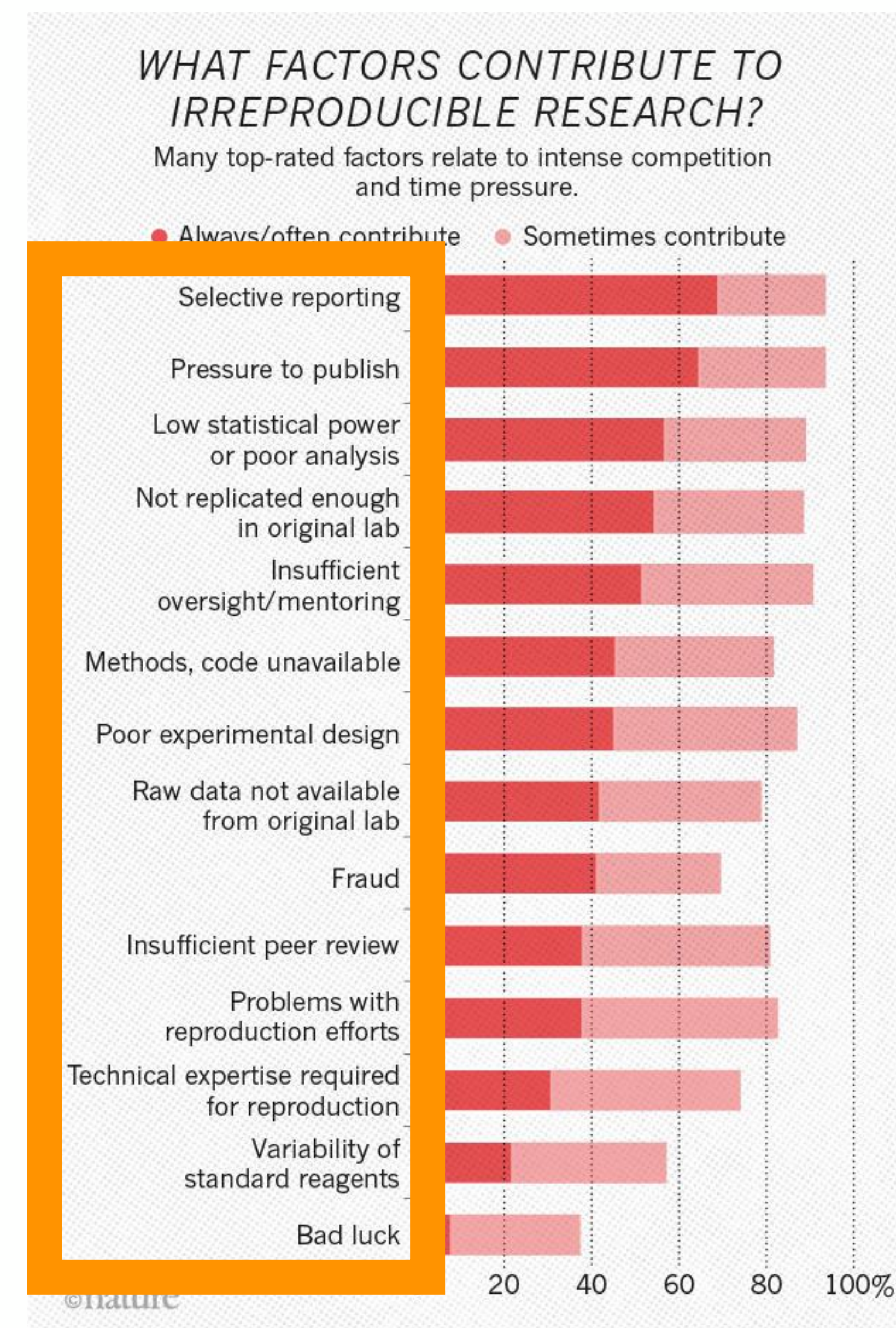
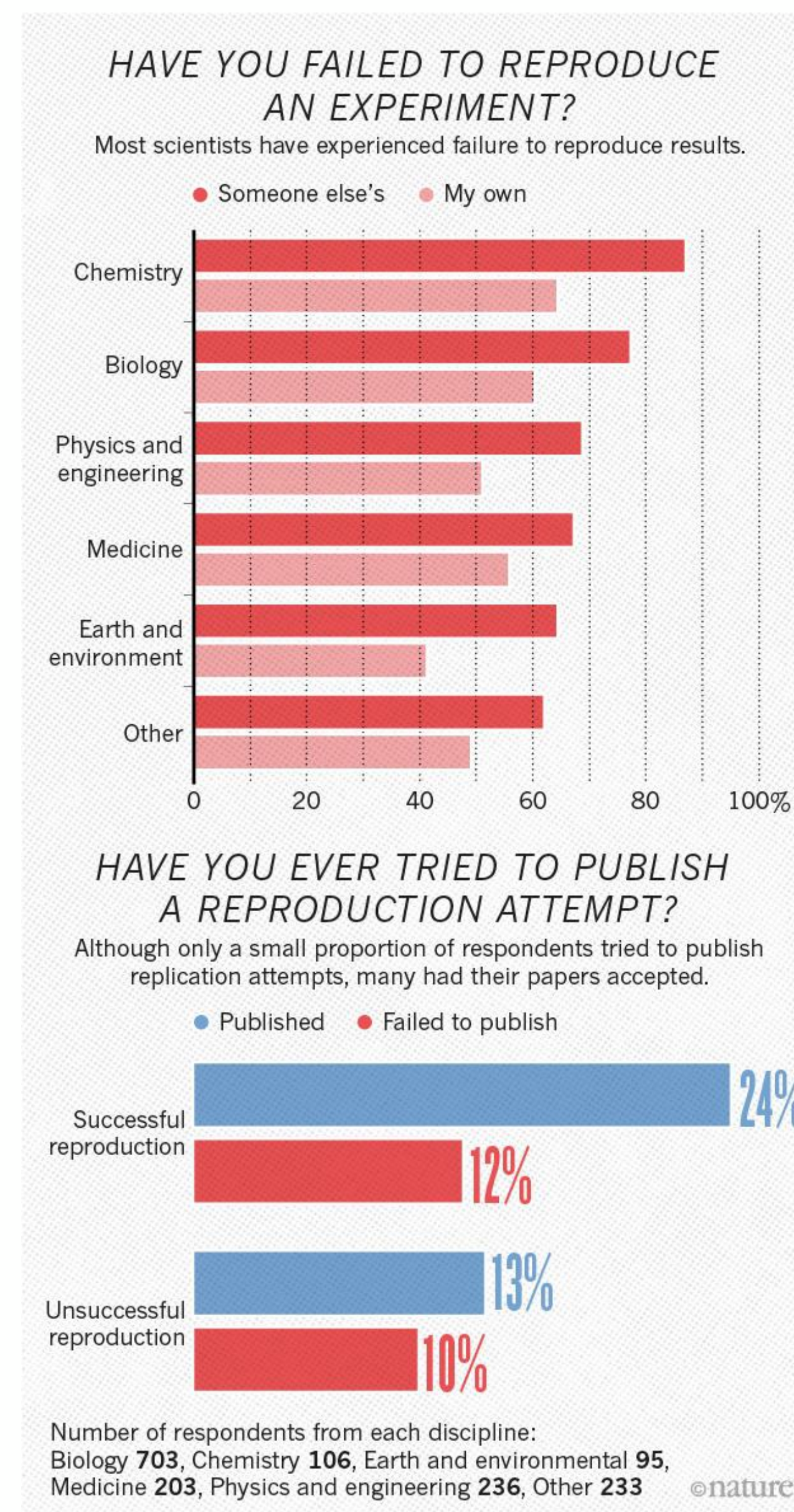
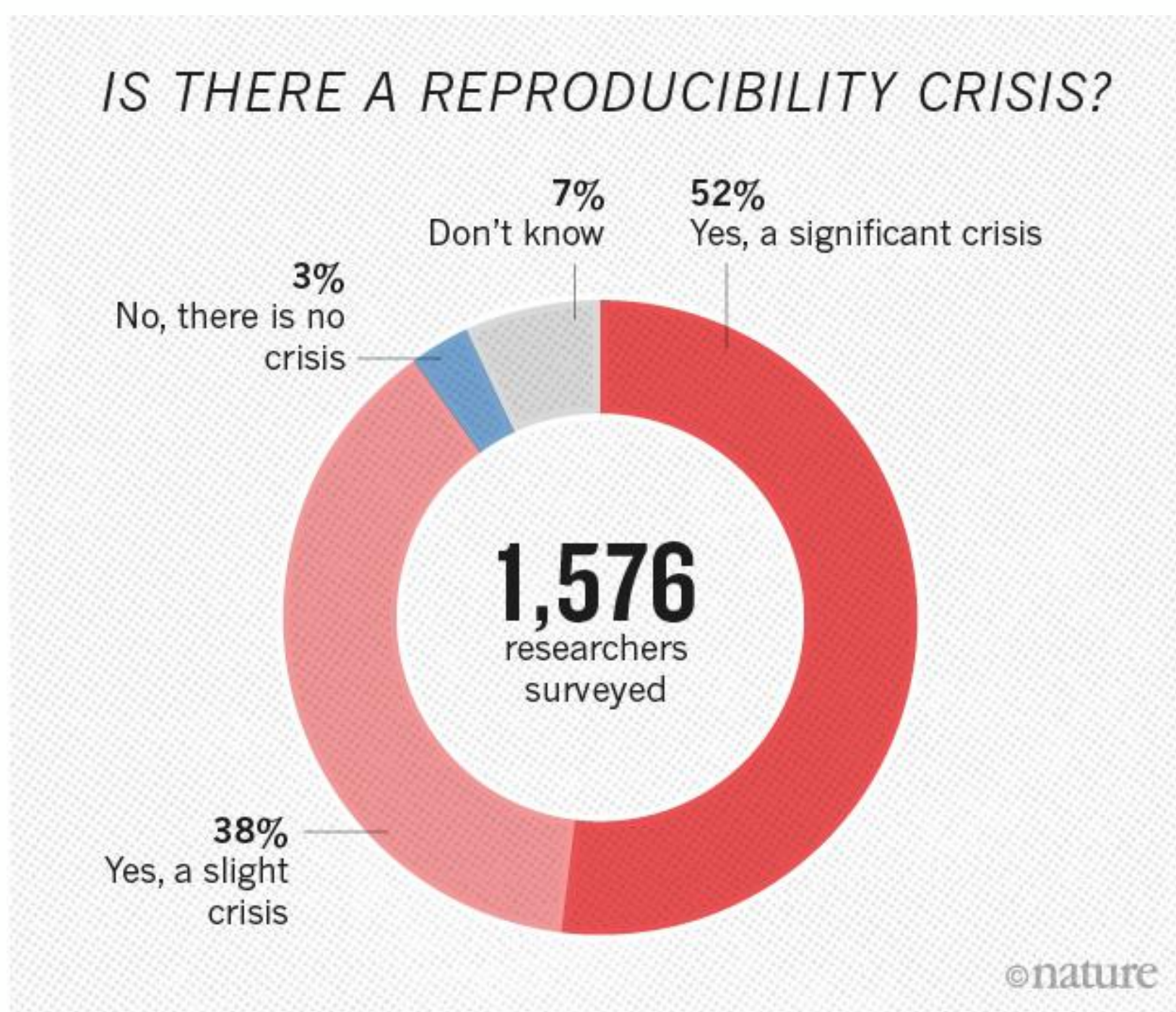


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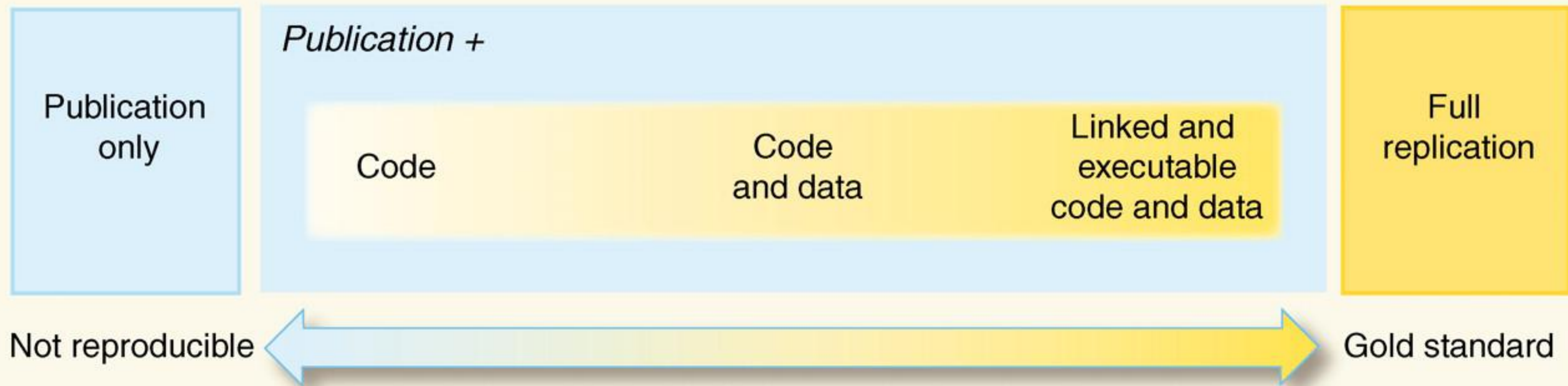
Baker (2016) <https://doi.org/10.1038/533452a>







## Reproducibility Spectrum



“Computational science has led to exciting new developments, but the nature of the work has exposed limitations in our ability to evaluate published findings. Reproducibility has the potential to serve as a minimum standard for judging scientific claims when full independent replication of a study is not possible.”

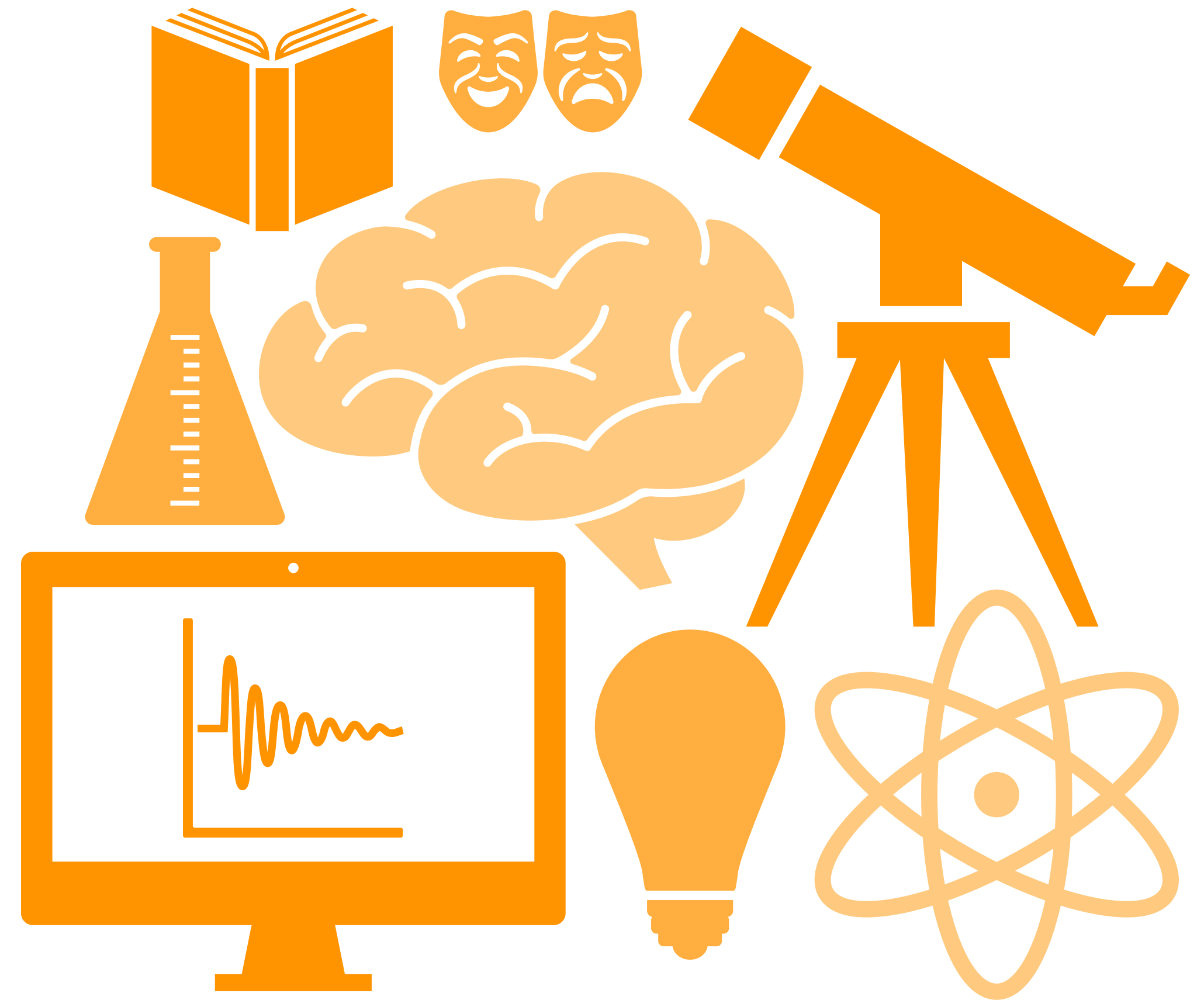
Peng (2011) <https://doi.org/10.1126/science.1213847>



# Research Culture

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- Encompasses the behaviours, values, expectations, attitudes, and norms of research communities.
- It affects who does research, what research is done, how it is done and how it is disseminated.
- There are ongoing concerns around issues such as: research integrity, career paths, permeability between sectors, recognition and reward, diversity, and support for collaboration and interdisciplinarity.



<https://royalsociety.org/topics-policy/projects/research-culture/>

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***All of the issues have the same underlying causes:***

**Highly competitive environment**

**+**

**Narrow definitions for success**

<https://royalsociety.org/topics-policy/projects/research-culture/>

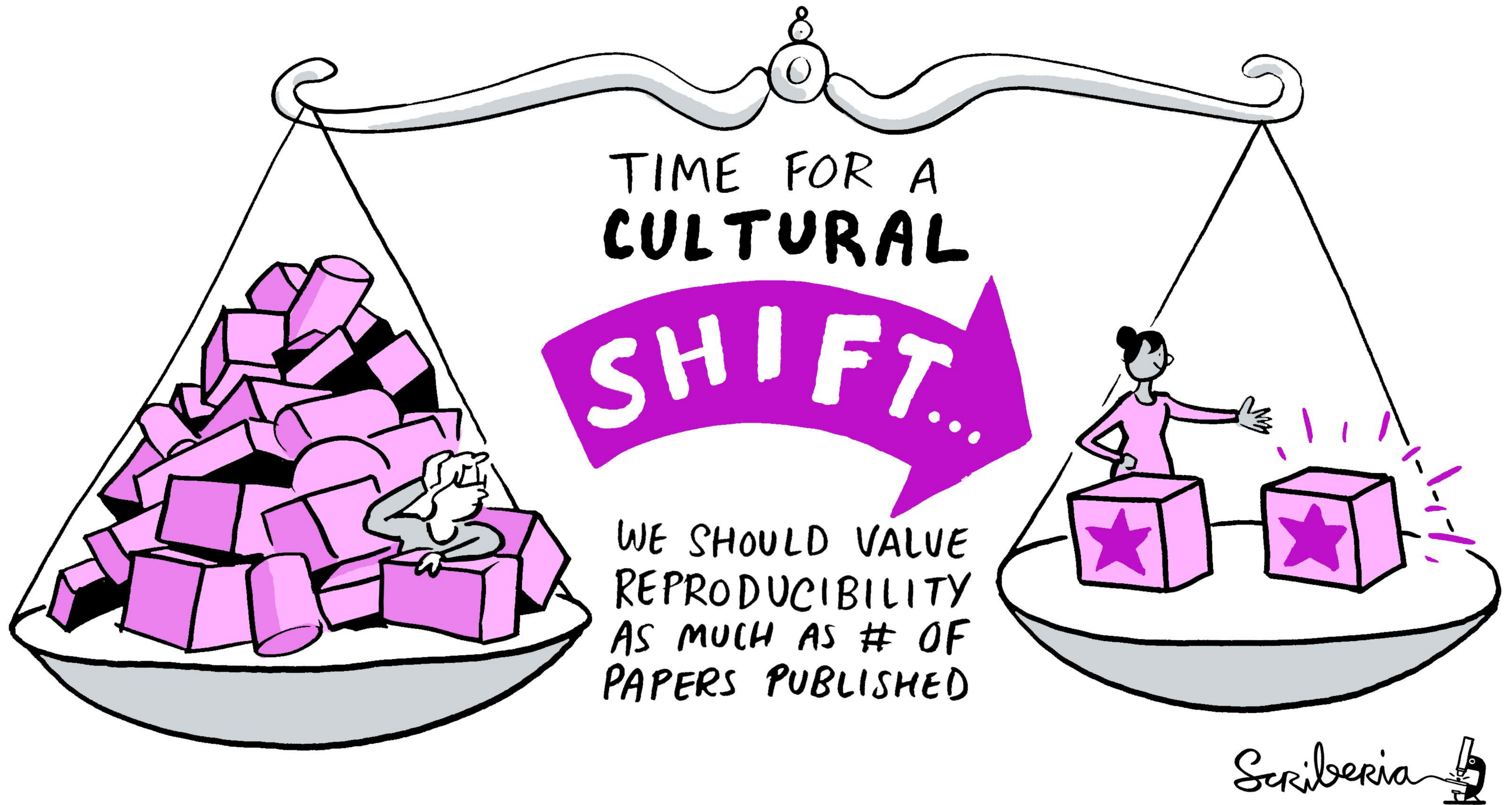
# Glasgow to rate 'collegiality' for professorial promotions

University believes new criteria rewarding selfless behaviour will 'focus minds'

- The University of Glasgow have introduced new promotion guidelines that require senior staff to demonstrate how they have helped others to succeed.
- From this month, they will ask all internal candidates applying for a professorship – as well as those professors seeking a higher professorial grade – to show their “collegiality” in each of the six areas in which their promotion will be assessed.
- That might include producing evidence that applicants:
  - Helped others to gain credit on major research projects
  - Nominated someone else for an award
  - Helped others to secure keynote speaker slots at conferences
  - Offered co-authoring opportunities
  - Acted as a second supervisor for junior colleagues supervising their first PhD students

Grove (2019) <https://www.timeshighereducation.com/news/glasgow-rate-collegiality-professorial-promotions>





The Turing Way Community and Scriberia, <http://doi.org/10.5281/zenodo.3332808>

# Open Science / Research / Scholarship



# What is Open Science?

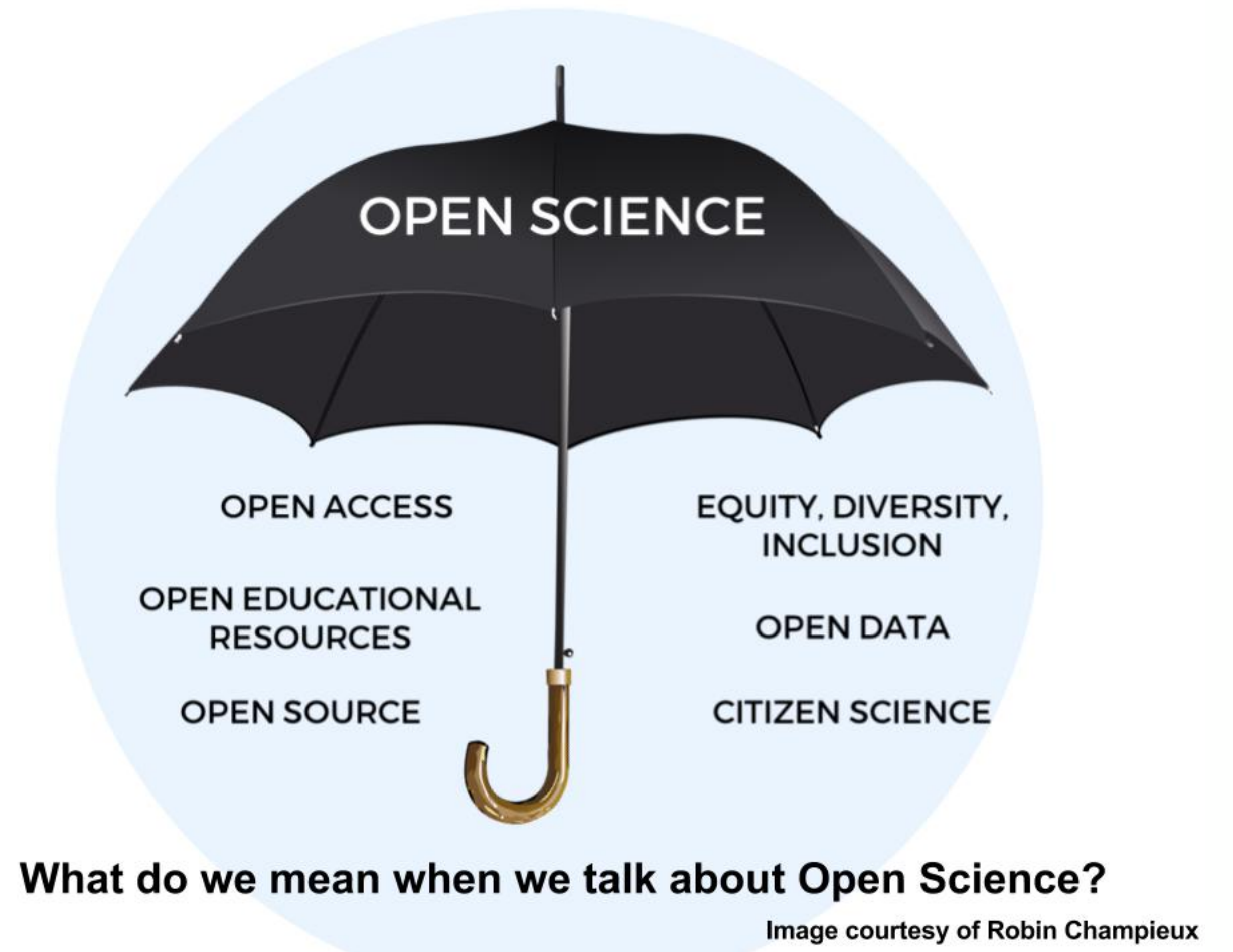
Open Science is the practice of science in such a way that others can collaborate and contribute, where research data, lab notes and other research processes are freely available, under terms that enable reuse, redistribution and reproduction of the research and its underlying data and methods.

... but isn't this just science?

Rephrase to Open Research or Scholarship to be inclusive of all research domains.

(FOSTER, Open Science Definition:

<https://www.fosteropenscience.eu/foster-taxonomy/open-science-definition>)





# Barriers to Open Research



# Barriers to Open Research

- Lack of awareness and training
- Cultural inertia and misinformation
- Challenging the establishment
- Follow the status quo to succeed
- Perceived lack of reward
- Not considered for promotion
- Requires additional skills
- Takes time
- Publication bias towards novel findings



Fig: McKiernan <http://whyopenresearch.org>

Whitaker (2018) <https://doi.org/10.6084/m9.figshare.7140050.v2>



# Barriers to Open Research

## Fear of

- Scooping or ideas being stolen
- Not being credited for ideas
- Errors and public humiliation
- Risk to reputation
- Reduced scientific quality
- Information overload



**SPRINGER NATURE**

Tennant (2017) <https://doi.org/10.6084/m9.figshare.5383711.v1>

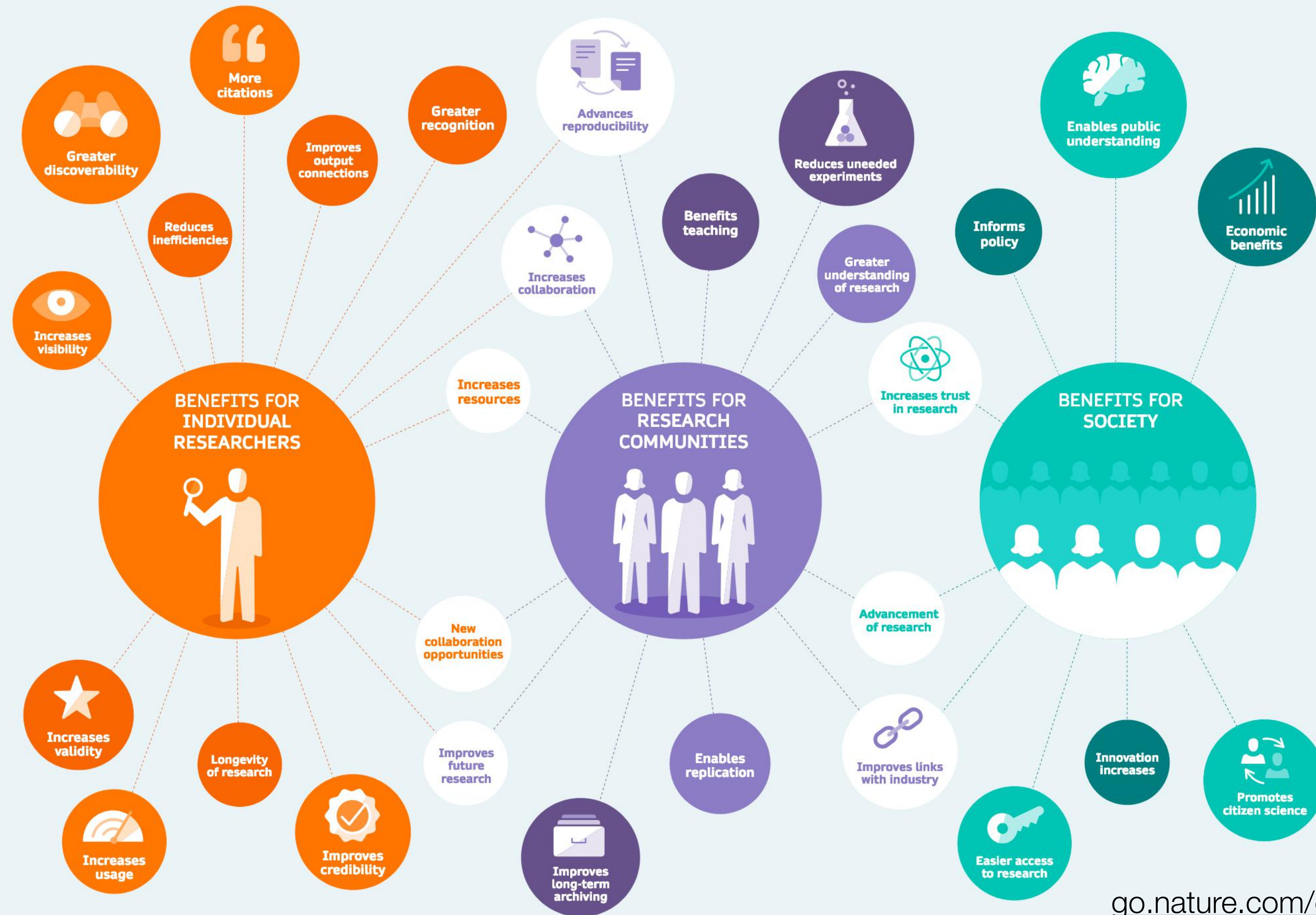
<https://doi.org/10.6084/m9.figshare.5558653>



# Why research openly?



# BENEFITS TO SHARING RESEARCH DATA



[go.nature.com/opendata](https://go.nature.com/opendata)






BIOCHEMISTRY AND CHEMICAL BIOLOGY



# Point of View: How open science helps researchers succeed



Erin C McKiernan , Philip E Bourne, C Titus Brown, Stuart Buck, Amye Kenall, Jennifer Lin, Damon McDougall, Brian A Nosek, Karthik Ram [see all »](#)  
 National Autonomous University of Mexico, Mexico; National Institutes of Health, United States; University of California, Davis, United States; Laura and John Arnold Foundation, United States; BioMed Central, United Kingdom; CrossRef, United Kingdom; University of Texas at Austin, United States; Center for Open Science, United States; University of California, Berkeley, United States [see all »](#)

FEATURE ARTICLE Jul 7, 2016

CITED 66 VIEWS 18,445 [ANNOTATIONS](#) **3**

CITE AS: eLife 2016;5:e16800 DOI: 10.7554/eLife.16800

Article

Figures and data

Side by side

► Jump to

## Abstract

Open access, open data, open source and other open scholarship practices are growing in popularity and necessity. However, widespread adoption of these practices has not yet been achieved. One reason is that researchers are uncertain about how sharing their work will affect their careers. We review literature demonstrating that open research is associated with increases in citations, media attention, potential collaborators, job opportunities and funding opportunities. These findings are evidence that open research practices bring significant benefits to researchers relative to more traditional closed practices.

<https://doi.org/10.7554/eLife.16800.001>

OF INTEREST

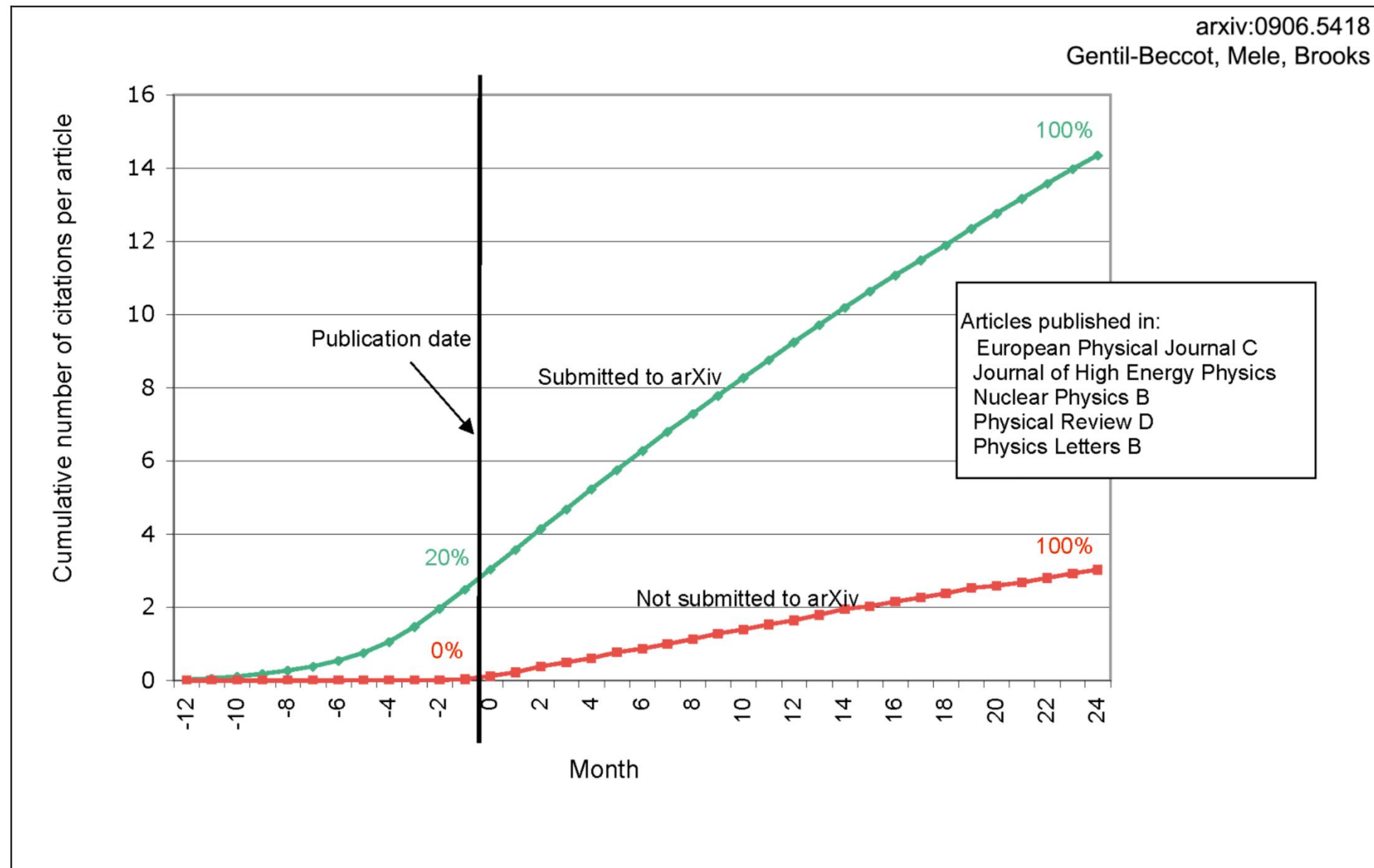
**In the open**

PODCAST

[Further reading »](#)



# Benefit to sharing preprints: more citations!



Gentil-Beccot, Mele, Brooks (2009), <https://arxiv.org/abs/0906.5418>



Your primary collaborator is yourself 6 months from now,  
and your past self doesn't answer emails.

– **Software Carpentry**

<https://dynamicceology.wordpress.com/2015/02/18/the-biggest-benefit-of-my-shift-to-r-reproducibility/>





# EU BUDGET FOR THE FUTURE

HORIZON EUROPE

#EUBudget #HorizonEU



**Open Science** will become the modus operandi of Horizon Europe. It will go beyond the open access policy of Horizon 2020 and require open access to publications, data, and to research data management plans.

[https://ec.europa.eu/commission/sites/beta-political/files/budget-may2018-research-innovation\\_en.pdf](https://ec.europa.eu/commission/sites/beta-political/files/budget-may2018-research-innovation_en.pdf)



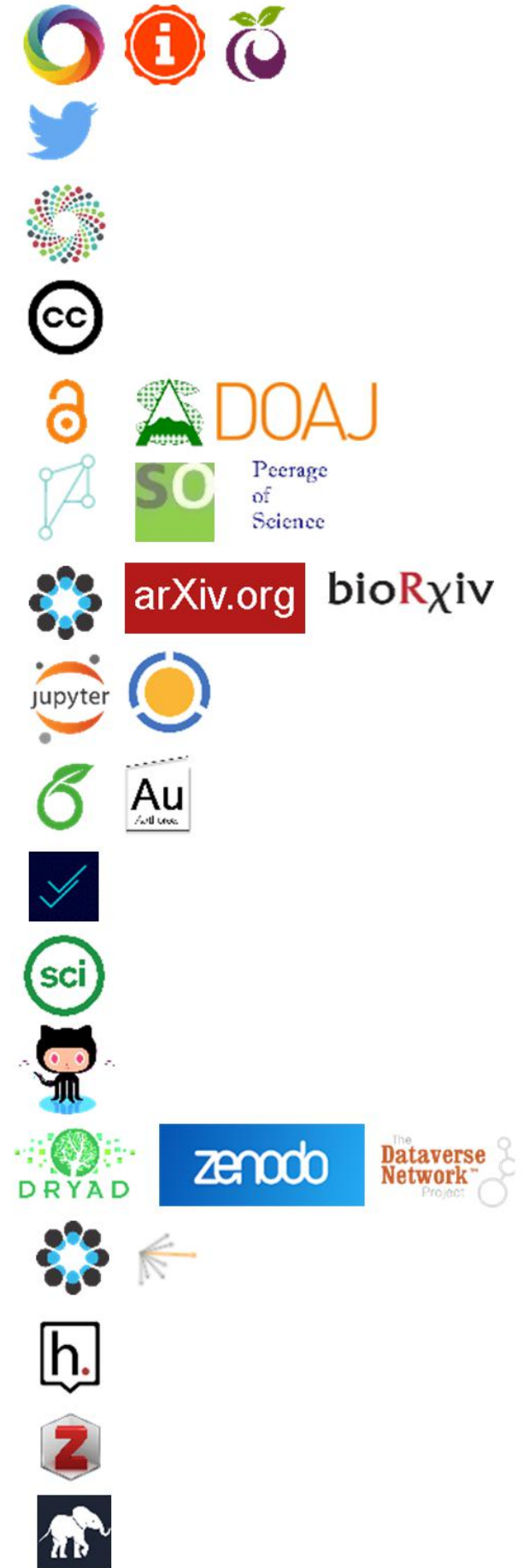
# How to open up your research workflow



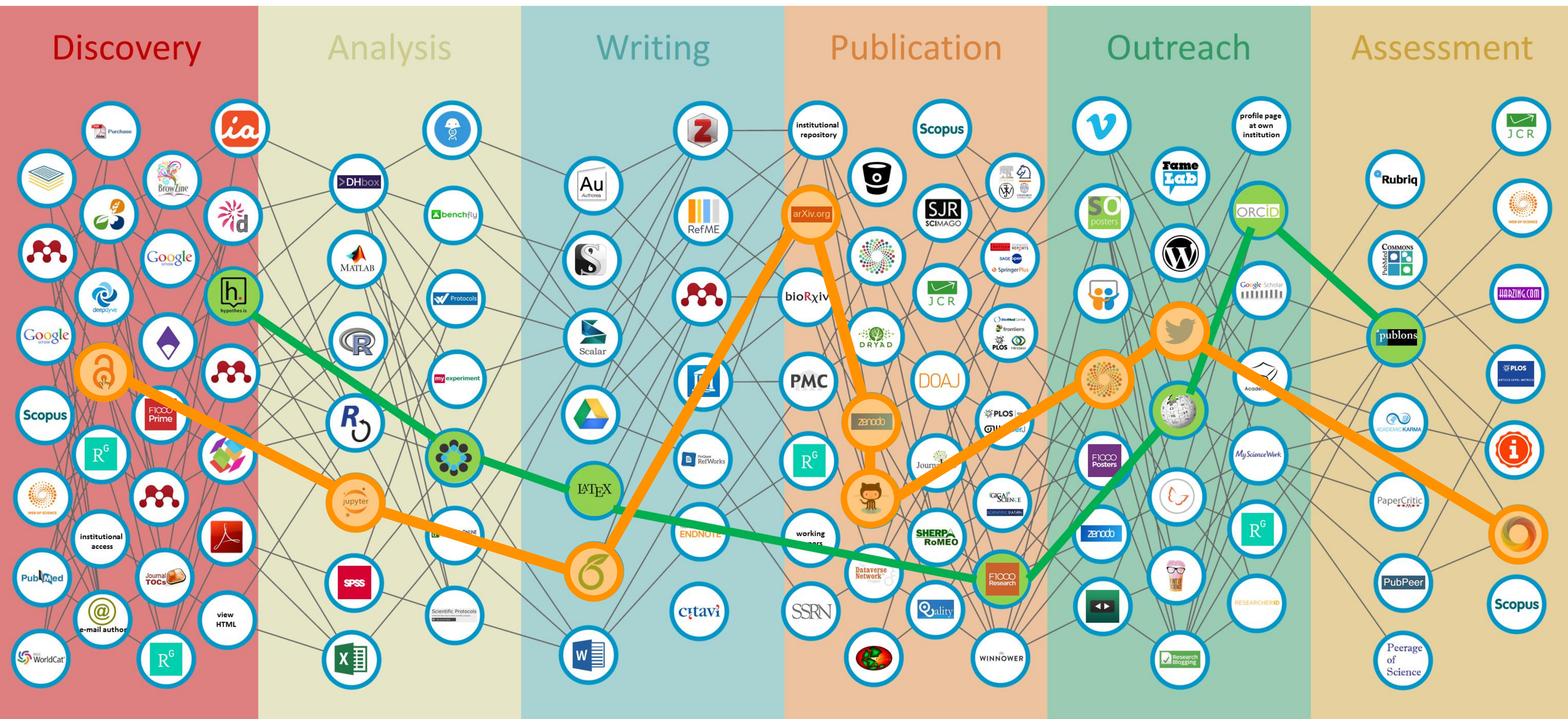
# You can make your workflow more open by...



- adding alternative evaluation, e.g. with altmetrics
- communicating through social media, e.g. Twitter
- sharing posters & presentations, e.g. at FigShare
- using open licenses, e.g. CC0 or CC-BY
- publishing open access, 'green' or 'gold'
- using open peer review, e.g. at journals or PubPeer
- sharing preprints, e.g. at OSF, arXiv or bioRxiv
- using actionable formats, e.g. with Jupyter or CoCalc
- open XML-drafting, e.g. at Overleaf or Authorea
- sharing protocols & workfl., e.g. at Protocols.io
- sharing notebooks, e.g. at OpenNotebookScience
- sharing code, e.g. at GitHub with GNU/MIT license
- sharing data, e.g. at Dryad, Zenodo or Dataverse
- pre-registering, e.g. at OSF or AsPredicted
- commenting openly, e.g. with Hypothes.is
- using shared reference libraries, e.g. with Zotero
- sharing (grant) proposals, e.g. at RIO



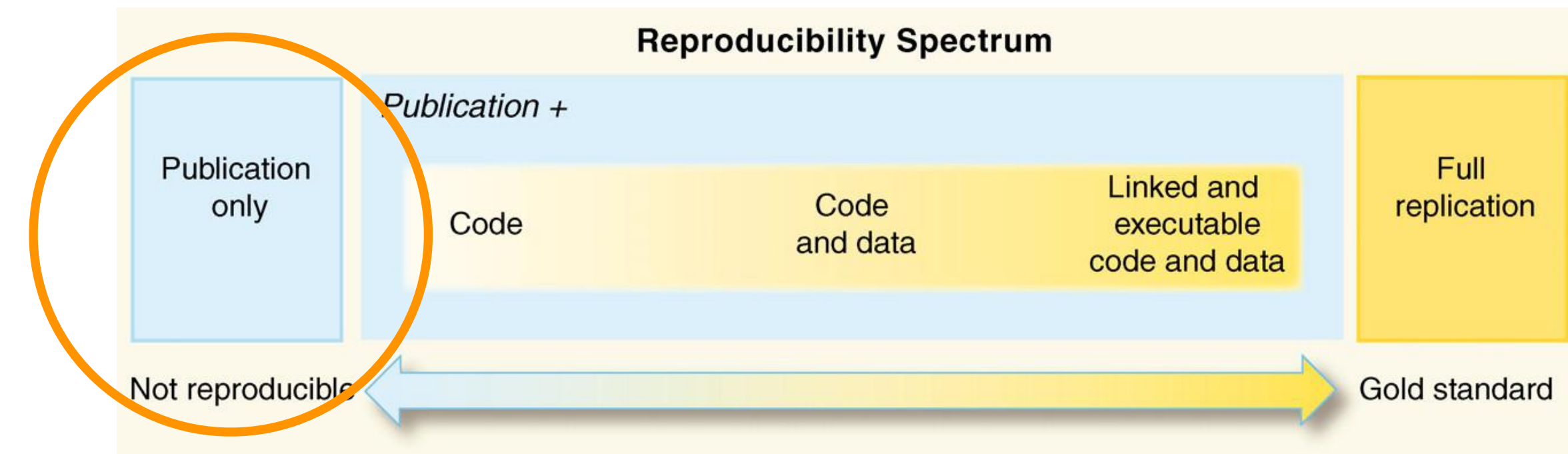




Jeroen Bosman and Bianca Kramer - <https://101innovations.wordpress.com/workflows/>



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Gold route by publishing OA, or  
Green route by self-archiving

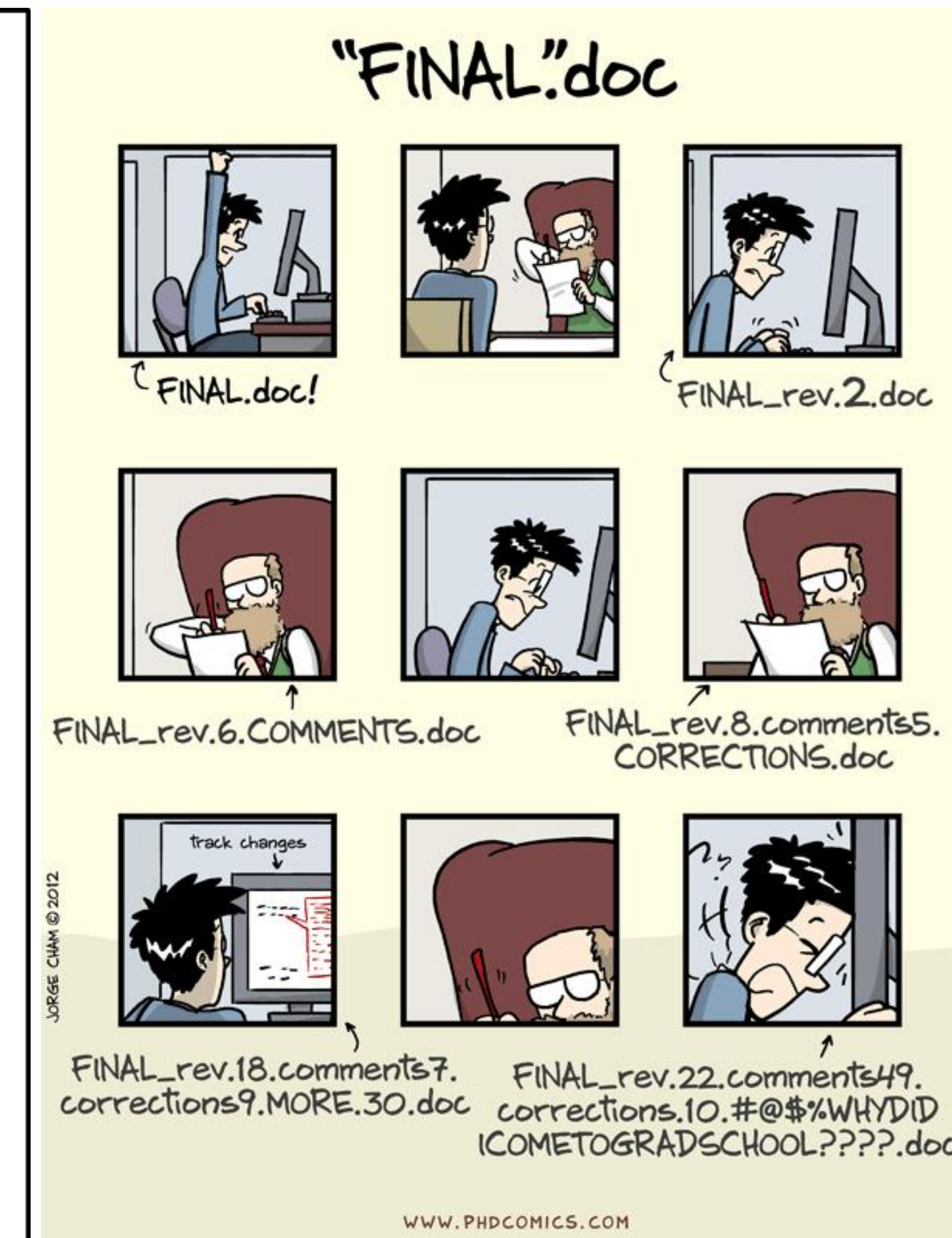
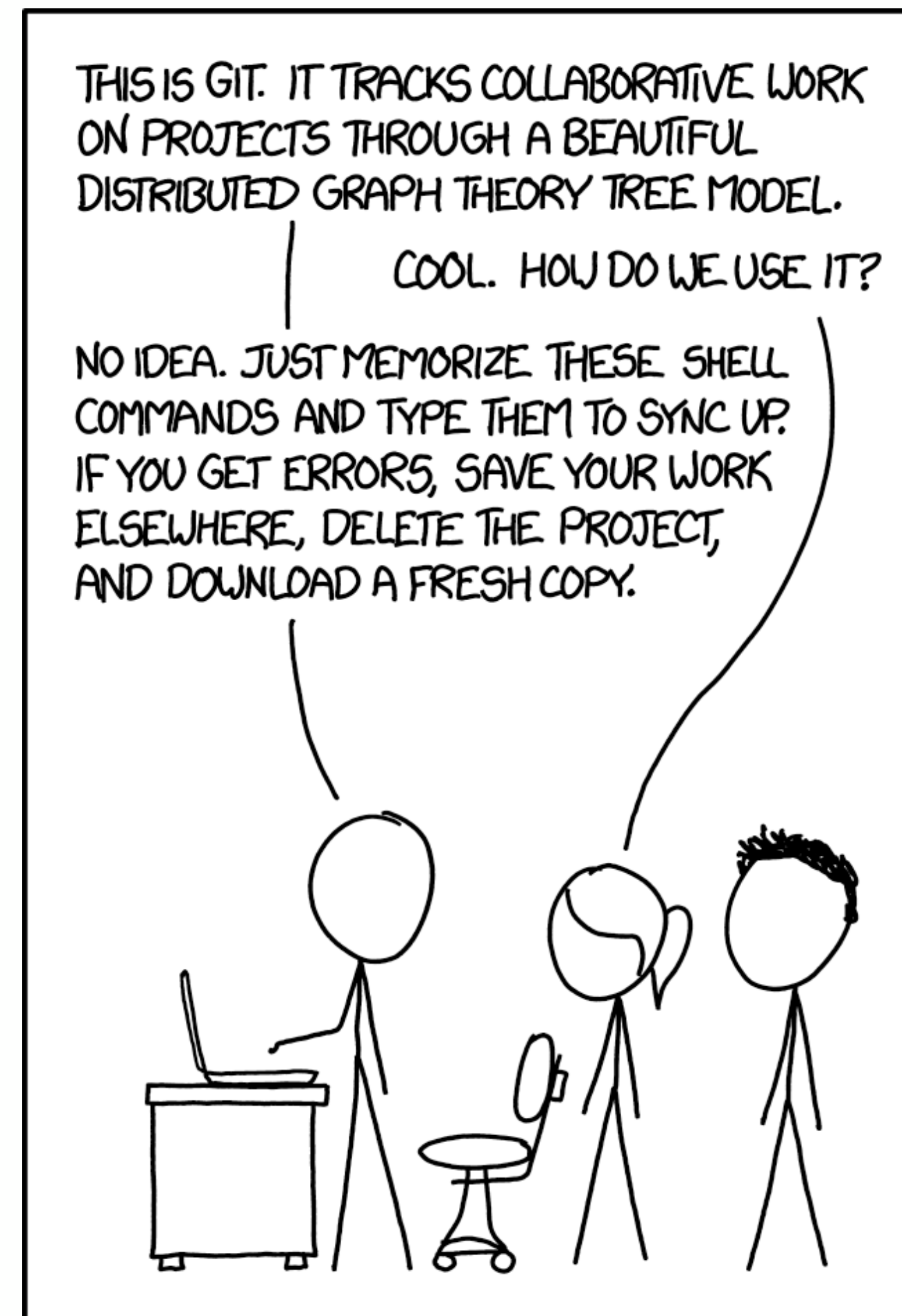
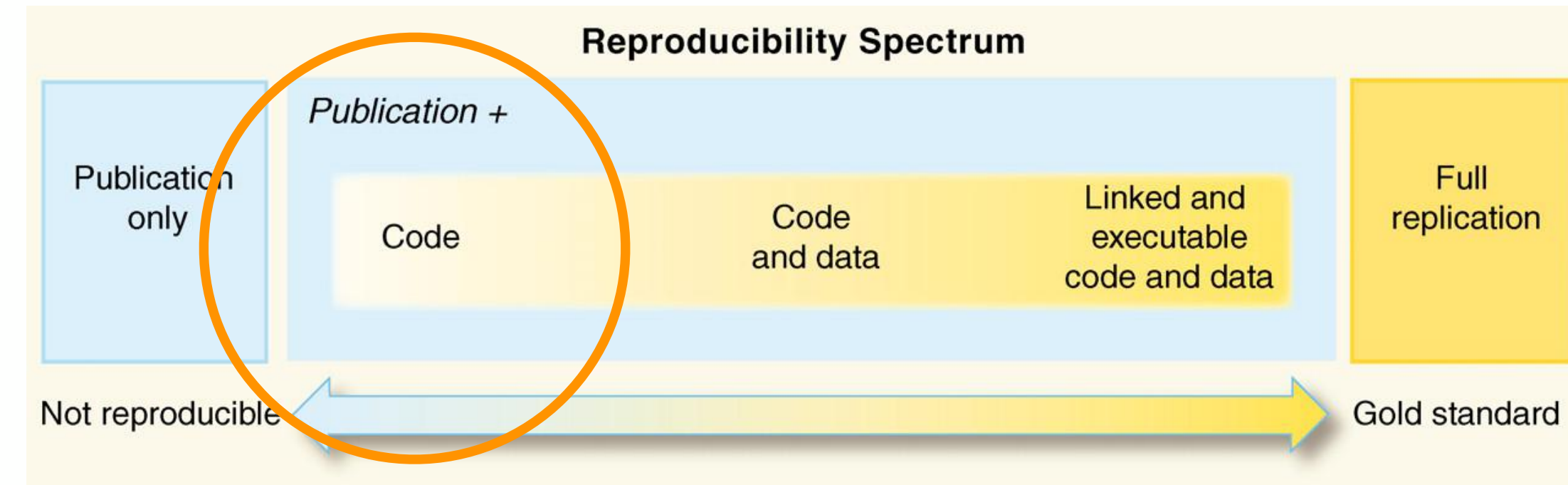


Jeroen Bosman and Bianca Kramer - <https://101innovations.wordpress.com>



# Share code & maintain version control using platforms such as Bitbucket, GitLab & GitHub

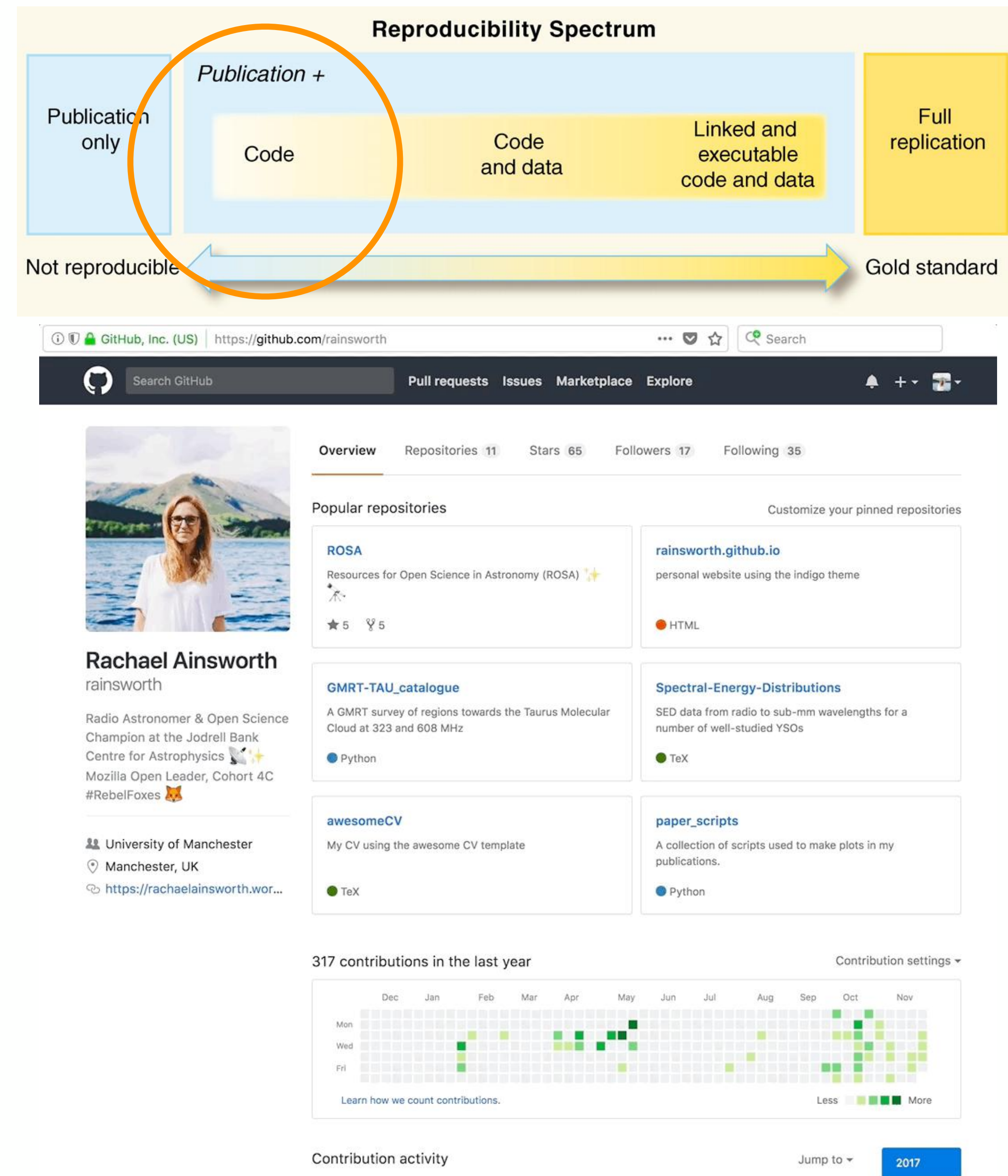
- Git is an open source program for tracking changes in text files (version control)
- GitHub is a code hosting platform for version control & collaboration. It lets you & others work together on projects from anywhere
- Facilitates open & reproducible science/code/research!
- Online portfolio & webpage for your research





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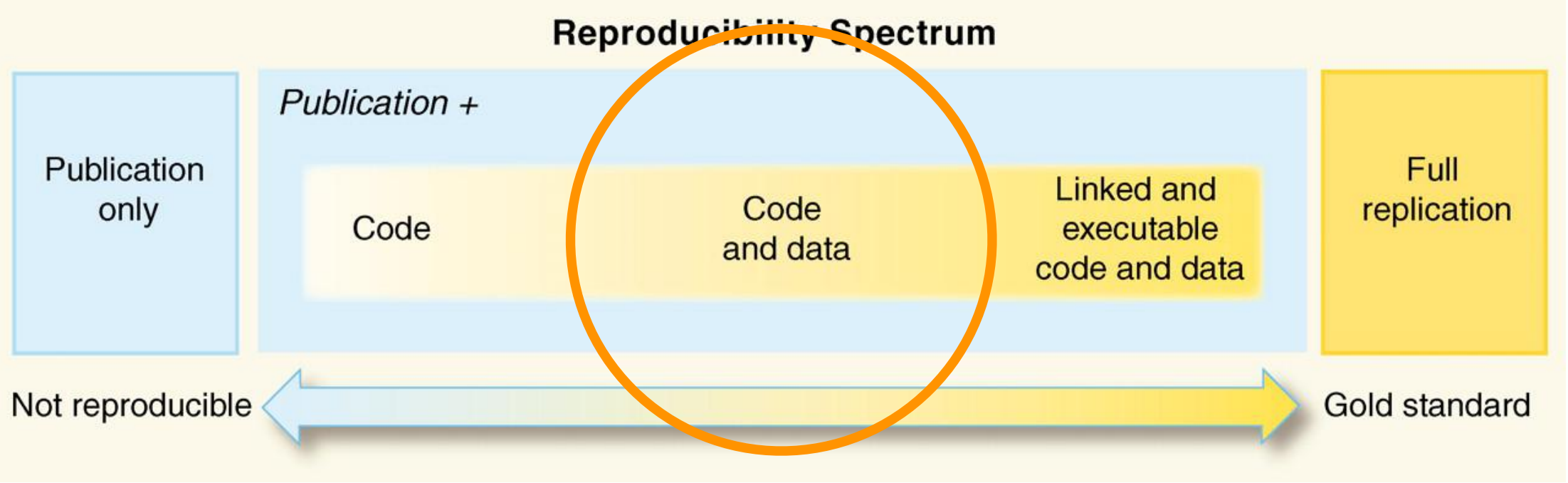




# Share research outputs in Open Repositories such as Figshare, Zenodo & the OSF

Catch-all repositories that enable researchers, scientists, projects & institutions to:

- Share research results in a wide variety of formats including text, datasets, audio, video & images across all fields of science
- Display their research results & get credited by making the research results citable & integrating them into existing reporting lines to funding agencies like the EU
- Easily access & reuse shared research results
- Archive your GitHub repository & make citable with Zenodo!



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rainswor@gmail.com

July 26, 2018

Preprint

Open Access

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### Constraining the nature of DG Tau A's thermal and non-thermal radio emission

Simon John Derek Purser, Rachael Ainsworth, Tom Ray, Dave Green, Andrew Taylor, Anna Scaife

DG Tau A, a class-II YSO known to drive a radio/optical, bipolar jet, is associated with both thermal, and non-thermal, radio emission. To investigate the nature of this emission, we present JVA 6 and 10 GHz observations with resolution of 1.7 and 1.9" respectively. Image noise levels range between 1.7 and 2.7 uJy/beam, making these the most sensitive observations of this target to date. No polarization is detected towards DG Tau A, or its associated radio knot C, with 3-sigma upper limits on the degree of linear polarization of <1.3, <50.8, <18.2 and <51.5% respectively. Proper motions are observed towards the non-thermal radio knot C, previously thought to be a bowshock. The nature, spatially resolved variability and offset from the central jet axis supports a scenario whereby it is instead a stationary shock driven into the surrounding medium by the jet. Towards the internal working surface, knot absolute velocity of 258+/-23 km/s, after correcting for inclination, using our measured proper motion and works. A spatially-resolved flux density increase of the red-shifted jet of DG Tau A is also seen, indicating the jet has probably undergone a variable mass loss event, the first time such an event has been observed in this target. For this ejection we measure a diameter of 101+/-34 au and, if optically thin, this indicates an ionised mass (3.7+/-1.0) x 10^-8 solar masses per year during the event. Since we do not see a contemporaneous ejection approaching jet, we conclude it to be an asymmetric process. Finally, using radiative transfer modelling towards the jet model, we find that the extent of the radio emission can only be explained with the presence of reionisation, in the flow.

Name	Size
DGTau_2012_Robust-2.8.5GHz.fits	4.7 MB
DGTau_2012_Robust0.5_5.5GHz.fits	4.9 MB
DGTau_2012_Robust0.5_8.5GHz.fits	1.1 MB
DGTau_2012_Robust2_5.5GHz.fits	4.9 MB
DGTau_2012_Robust2.8.5GHz.fits	783.4 kB
DGTau_2016_Robust-2_10GHz.fits	17.3 MB
DGTau_2016_Robust-2.8.5GHz.fits	4.7 MB
DGTau_2016_Robust0.5_10GHz.fits	4.7 MB

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October 17, 2018

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### Reproducibility and Open Science

Ainsworth, Rachael

Presentation slides in both .pptx and .pdf formats for an invited talk I gave at the Alan Turing Institute in the British Library as part of the Data Science for Experimental Design workshop on 17 October 2018.

Abstract: Making research results more accessible and reproducible can contribute to better and more efficient science, however widespread adoption of open research practices has not yet been achieved. Funding agencies (such as the European Commission Horizon 2020) are increasingly requiring research products (such as data and publications) to be made openly available in order to make results more accessible, transparent and reproducible. Recent studies have also shown that open research practices are associated with benefits to the researcher such as increases in citations, media attention, potential collaborators, job and funding opportunities. In this talk I will discuss the different aspects of Open Science, the barriers we face to practicing openly, how to 'open' up your research workflow using open and transparent data and software services in order to reap the benefits associated with open research practices, and highlight current open projects in STEM.

Preview

Indexed in

OpenAIRE

Publication date:

October 17, 2018

DOI:

DOI: 10.5281/zenodo.1464853

Keyword(s):

Reproducibility Open Science Data Science

Meeting:

Data Science for Experimental Design (DSED), The Alan Turing Institute, London, UK, 17 October 2018

License (for files):

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Versions



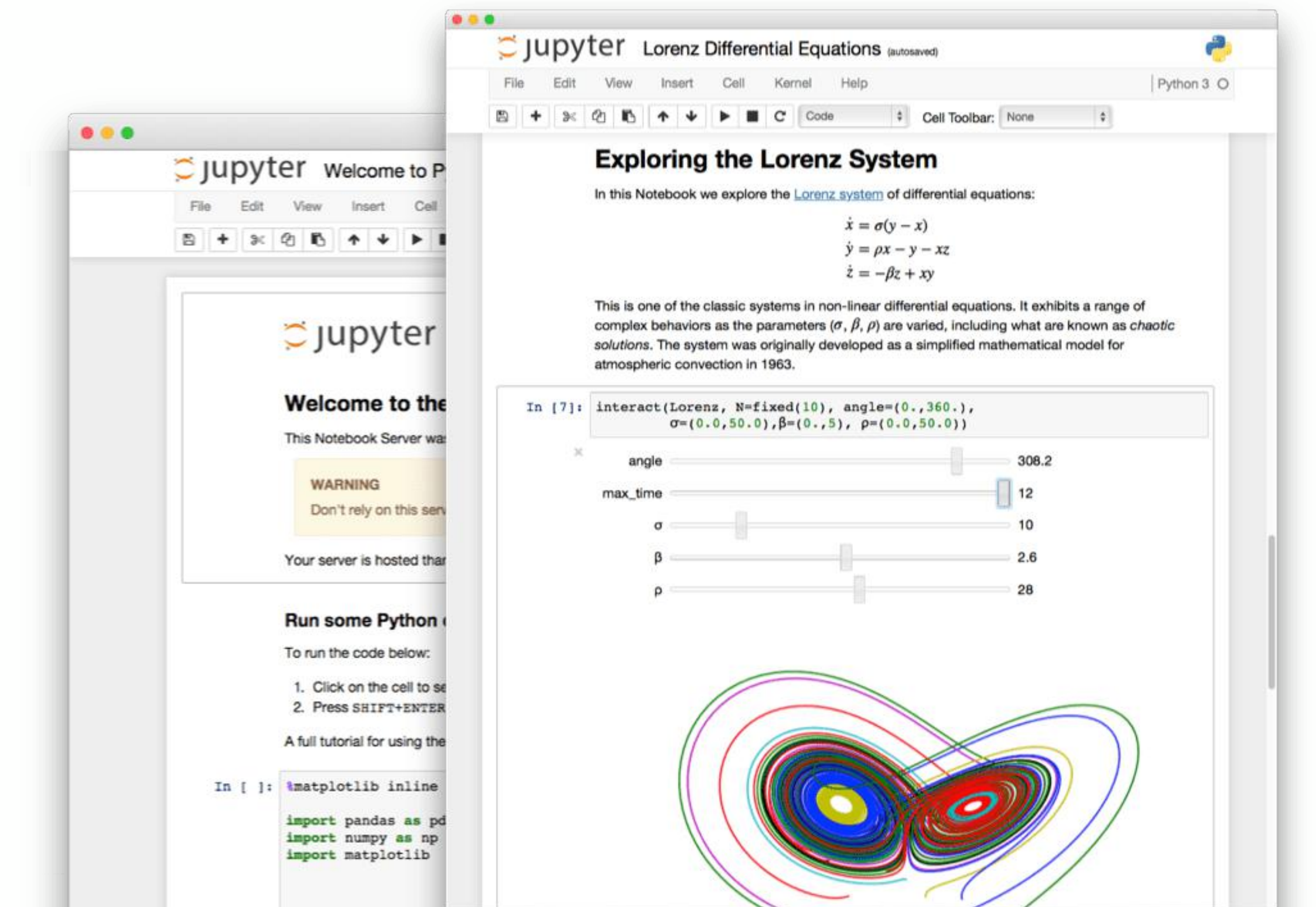
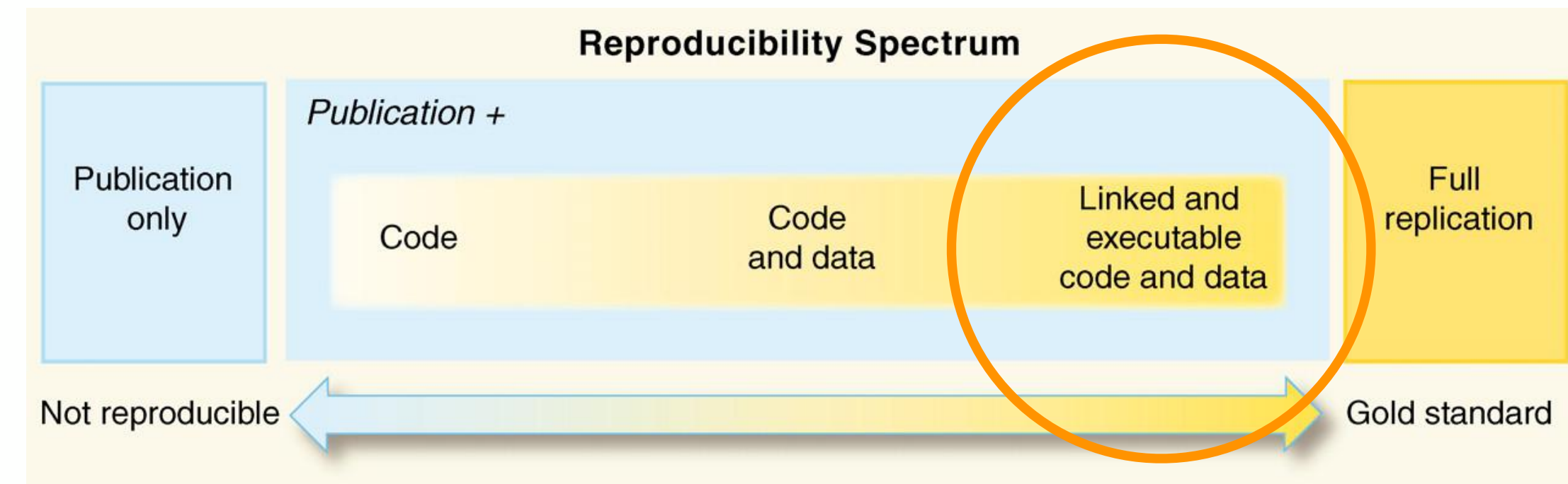
# Share analyses using Open Notebooks such as Jupyter & RStudio

Open Notebooks are documents that contain equations, visualisations, narrative text and live code that can be executed independently and interactively, with output visible immediately beneath the input.

They bring together analysis descriptions and results, which can be executed to perform the data analysis in real time.

Added value:

- Transparency in the analysis of the data
- Reproducibility
- Documentation of the entire workflow



<https://jupyter.org/>



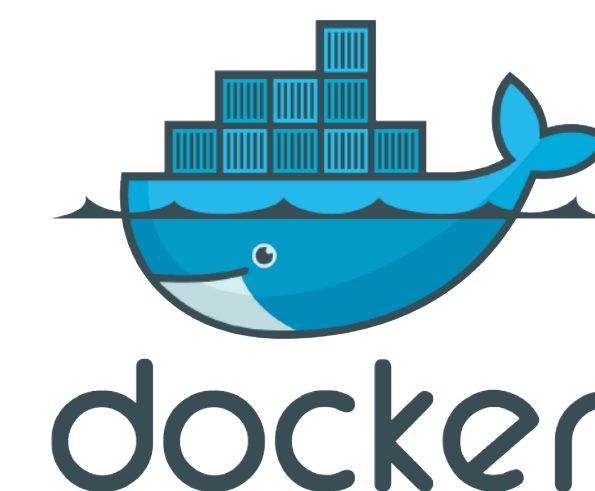
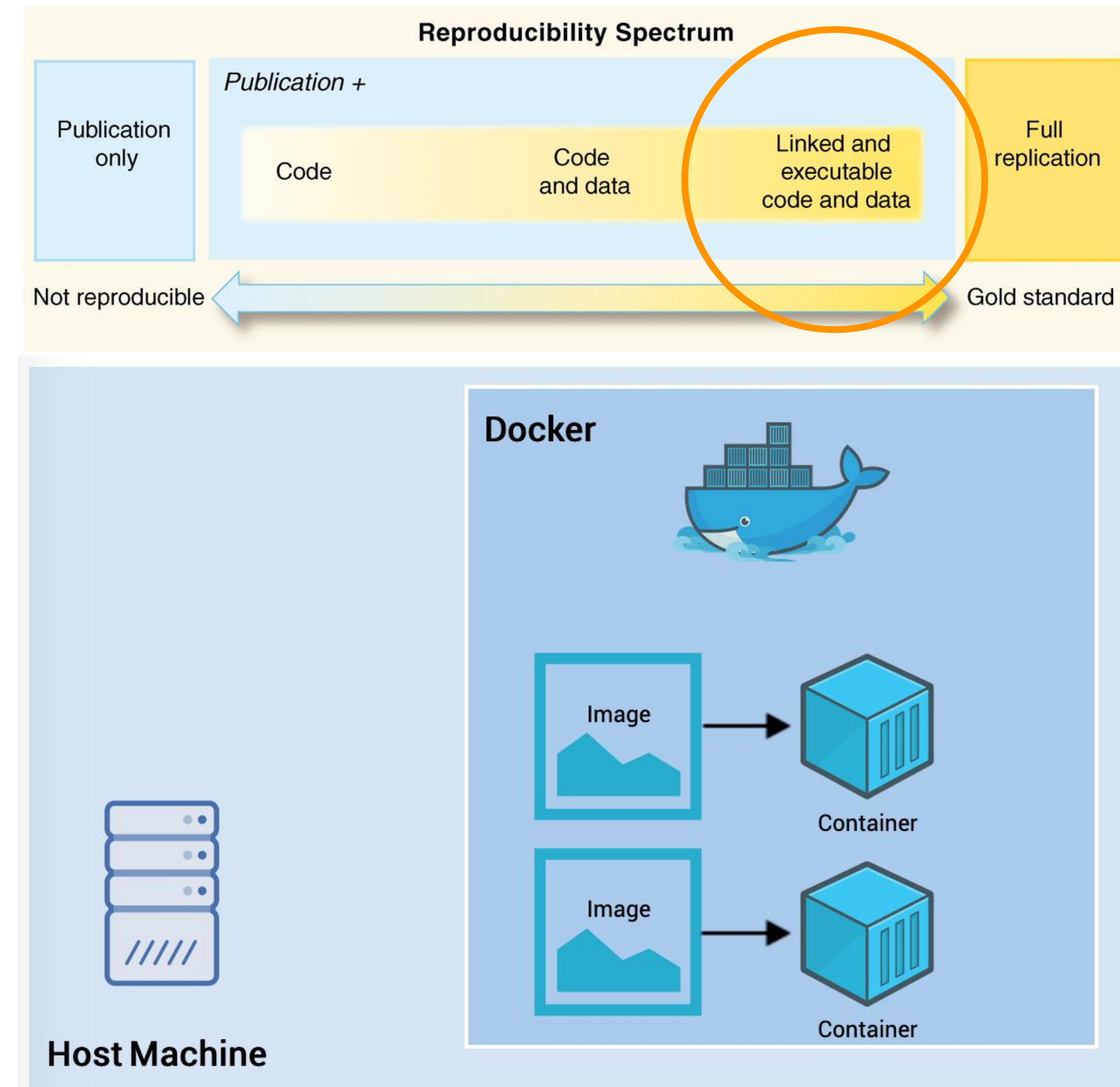
# Package data, code & analyses through Containerisation such as with Docker & Singularity

A container image is a lightweight, standalone, executable package of software that includes everything needed to run an application: code, runtime, system tools, system libraries and settings.

Containers can be used to package entire scientific workflows, software and libraries, and even data. This means that you don't have to ask your cluster admin to install anything for you - you can put it in a container and run.

Need to share your code? Put it in a container and your collaborator won't have to go through the pain of installing missing dependencies.

Avoids the “but it worked on *my* laptop...” problem.

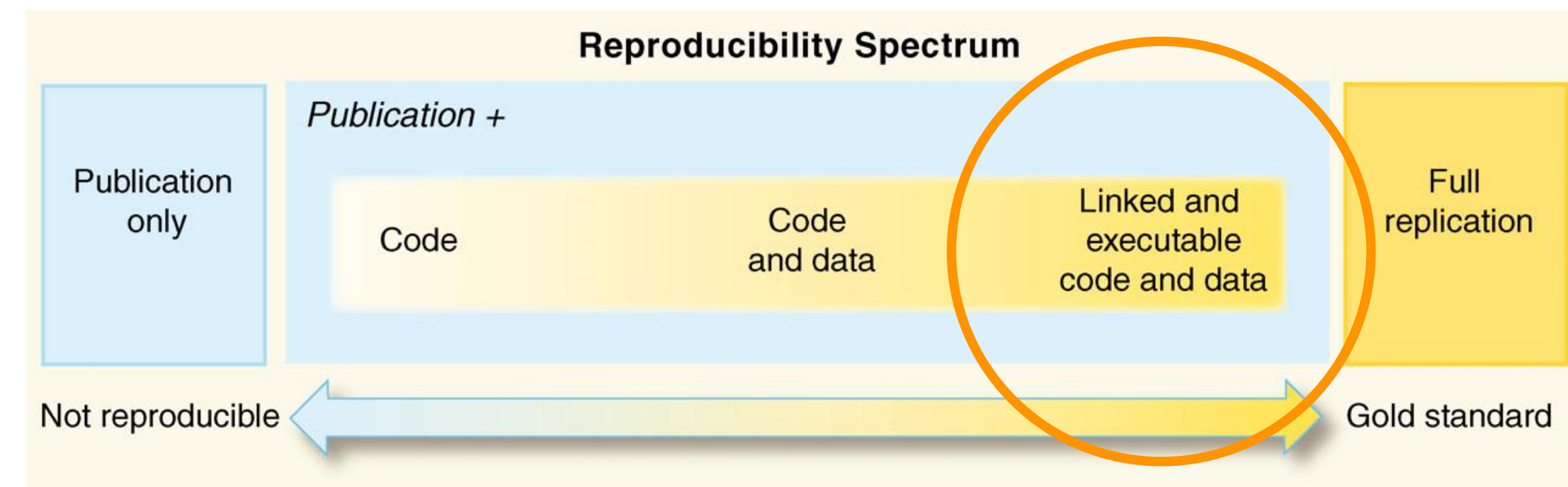




# Don't want to build your own container? Use Binder!

- Makes it simple to generate reproducible computing environments from a Git repository.
- Generates a Docker image from this repository which will have all the components that you specify along with the Jupyter Notebooks inside.
- You will be able to share a URL with users that can immediately begin interacting with this environment via the cloud.
- Binder's goal is to enable as many analytic workflows as possible.

[mybinder.org](https://mybinder.org)



## Turn a Git repo into a collection of interactive notebooks

Have a repository full of Jupyter notebooks? With Binder, open those notebooks in an executable environment, making your code immediately reproducible by anyone, anywhere.

Build and launch a repository

GitHub repository name or URL

GitHub ▾

Git branch, tag, or commit

Path to a notebook file (optional)

File ▾launch

Copy the URL below and share your Binder with others:



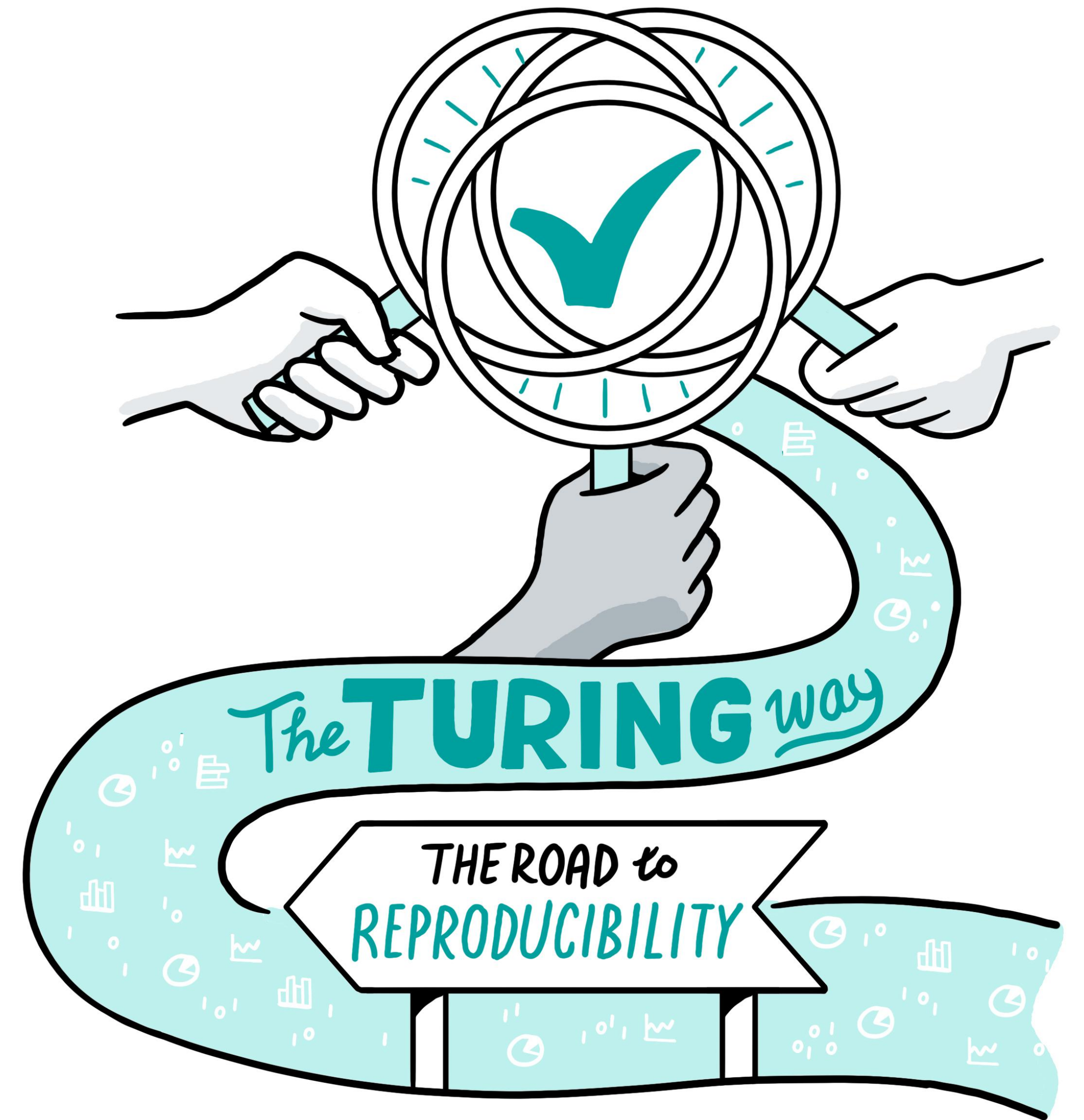
Copy the text below, then paste into your README to show a binder badge: 





# The Turing Way

- Project led by Kirstie Whitaker at The Alan Turing Institute to make reproducible research “too easy not to do”
- In short: *The Turing Way* encompasses a handbook, community, collaboration, workshops and training
- Team of researchers, research software engineers, librarians and YOU!
- Demonstrates open and transparent project management and communication with future users, as it is openly developed at our GitHub repository: <https://github.com/alan-turing-institute/the-turing-way>



The Turing Way Community and Scriberia  
<http://doi.org/10.5281/zenodo.3332808>

Scriberia 



# Open Science in Astronomy & a case study



# Open Science in Astronomy

## Open Access:

- arXiv! Started in August 1991 and provides open access to 1,517,000+ e-prints in (Astro)Physics and many other fields

## Open Data:

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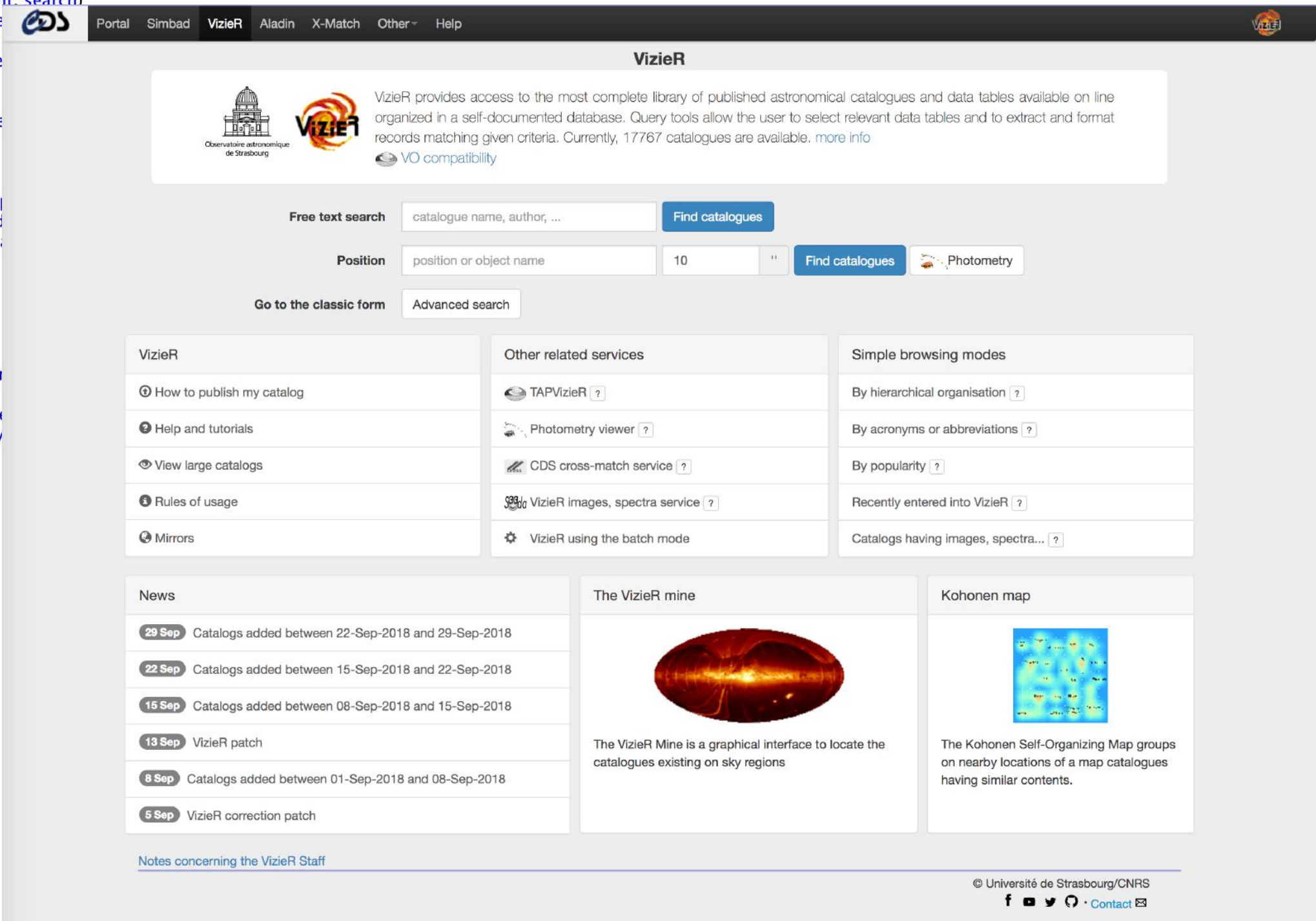
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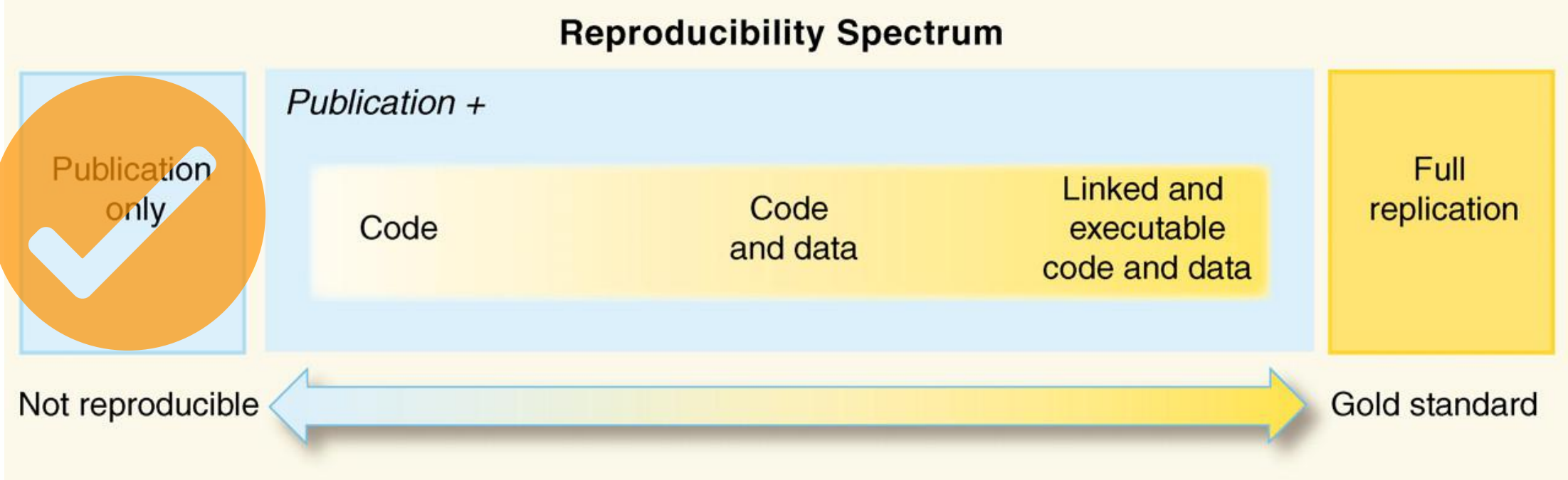
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<http://ileo.de/2017/11/13/astronomy-as-an-example-for-an-open-science/>



# Open Access to publication



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Astrophysics > High Energy Astrophysical Phenomena

## Constraining Redshifts of Unlocalised Fast Radio Bursts

C. R. H. Walker, Y.-Z. Ma, R. P. Breton

(Submitted on 4 Apr 2018)

The population of fast radio bursts (FRBs) will continue to diverge into two groups depending on their method of discovery: those which can be localised, and those which cannot. Events potentially less useful for astronomical and cosmological purposes due to limited localisation will accumulate with the advent of new facilities and continued efforts by, e.g., the SUPERB collaboration, which may require afterglows or multi-wavelength counterparts for sub-arcsecond localisation. It is important to exploit these sources to their maximum scientific potential. We perform analysis of FRB dispersion measures (DMs), considering different theoretical FRB progenitors with view to place more rigorous constraints on FRB redshifts, in particular for large statistical samples, via their DMs. We review FRB DM components, and build redshift-scalable probability distributions corresponding to different progenitor scenarios. We combine these components into a framework for obtaining FRB DM probabilities given their redshifts. Taking into account different possibilities for the evolution of progenitors across cosmic time we invert this model, thus deriving redshift constraints. Effects of varying FRB progenitor models are illustrated. While, as expected, host galaxy DM contributions become decreasingly important with increasing redshift, for AGN-like progenitor scenarios they could remain significant out to redshift 3. Constraints are placed on redshifts of catalogued FRBs with various models and increasingly realistic models may be employed as general understanding of FRBs improves. For localised FRBs, we highlight future prospects for disentangling host and intergalactic medium DM components using their respective redshift scaling. We identify a use for large samples of unlocalised FRBs resulting from upcoming flux-limited surveys, such as with CHIME, in mapping out the Milky Way contribution to the DM.

Comments: 13 pages, 8 figures, submitted for publication in Astronomy & Astrophysics on 04/04/2018

Subjects: High Energy Astrophysical Phenomena (astro-ph.HE)

Cite as: arXiv:1804.01548 [astro-ph.HE]

(or arXiv:1804.01548v1 [astro-ph.HE] for this version)

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### 4.4. Concluding remarks

We present a framework for exploration of the statistical relationship between FRB redshifts and dispersion measures, which provides the basis for:

1. Qualitative assessment of host galaxy contributions to FRB DMs using realistic models. We find that all our host models may contribute large amounts of DM ( $> 400 \text{ pc cm}^{-3}$ ) in the rest frame, and as expected, that  $\text{DM}_{\text{host}}$  is most significant for FRBs of lower source redshifts, becoming negligible as redshift increases. For the most extreme scenarios where FRBs originate close to galactic centers, this component still contributes significantly to overall  $P(\text{DM}|z_s)$  profiles out to  $z_s = 3$ .
2. More rigorous uncertainties to be placed on FRB redshifts than are currently standard practice. By consulting  $P(z_s|\text{DM})$  probability distributions created from our (or similar) models, this may additionally provide an innovative way to narrow down the potential host galaxies for unlocalised FRBs, and allow insight into FRB progenitors to be drawn from large source populations. A repository containing our Python code and examples may be found online at <https://doi.org/10.5281/zenodo.1209920>.
3. The disentanglement of individual FRB dispersion measure components. For example, the MW components for given sightlines could be extracted from  $\text{DM}_{\text{obs}}$  by comparing DM probability distributions from a flux-limited survey (e.g. CHIME) at different sky locations and looking for systematic offsets in their profiles. This technique would not require redshift measurements, thus further increasing the usefulness of unlocalised FRBs. It also could be possible to separate  $\text{DM}_{\text{IGM}}$  and  $\text{DM}_{\text{host}}$  using their respective redshift dependences.

Walker, Ma & Breton, <https://arxiv.org/abs/1804.01548>



# Open Access to code & data

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April 2, 2018

Software

Open Access

mbcxqcw2/EEModel: Master DOI release

mbcxqcw2

Updated zenodo DOI link to always link to the latest github version

Preview

EEModel-v1.03.zip

mbcxqcw2-EEModel-268b3da

ExcessElectronLib.py

ExcessElectronModel.ipynb

FRBcat\_FRB\_DMs.csv

README.md

cosmo\_consts.py

host\_galaxies

lin\_mp\_files

18.1 kB

505.5 kB

2.2 kB

760 Bytes

907 Bytes

17.8 MB

17.8 MB

17.8 MB

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21.5 kB

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Files (39.6 MB)

Name	Size	Preview	Download
mbcxqcw2/EEModel-v1.03.zip	39.6 MB		

md5:e8e62d8974085cea865f585488722a0b

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Publication date: April 2, 2018

DOI: 10.5281/zenodo.1211089

Related identifiers: Supplement to: https://github.com/mbcxqcw2/EEModel/tree/v1.03

License (for files): Other (Open)

Versions

Version	Date
Version v1.03	Apr 2, 2018
Version v1.0.2	Mar 30, 2018
Version v1.0.1	Mar 30, 2018
Version v1.0.0	Mar 29, 2018

Cite all versions? You can cite all versions by using the DOI 10.5281/zenodo.1209920. This DOI represents all versions, and will always resolve to the latest one. Read more.

<https://zenodo.org/record/1211089>

Reproducibility Spectrum

Publication only

Publication + Code

Code and data

Linked and executable code and data

Full replication

Not reproducible ← Gold standard

Search or jump to...

Pull requests

Issues

Marketplace

Explore

mbcxqcw2 / EEModel

Watch 1

Unstar 1

Fork 0

Code

Issues 0

Pull requests 0

Projects 0

Wiki

Security

Insights

Extragalactic Electron Model

17 commits

1 branch

4 releases

1 contributor

Tag: v1.03

New pull request

Create new file

Upload files

Find File

Clone or download

mbcxqcw2 Updated readme with all version zenodo doi

Latest commit 268b3da on Apr 2, 2018

host_galaxies	adding files	last year
lin_mp_files	adding files	last year
ExcessElectronLib.py	Updated ExcessElectronLib with Planck references	last year
ExcessElectronModel.ipynb	updated notebook to link with extra host data	last year
FRBcat_FRB_DMs.csv	added FRB list from FRBcat	last year
README.md	Updated readme with all version zenodo doi	last year
cosmo_consts.py	updated cosmology constants	last year
linear_growth_factor.py	adding files	last year
requirements.txt	changing requirements.txt	last year
runtime.txt	added runtime document for python 2.7 binder compatibility	last year

launch binder

<https://github.com/mbcxqcw2/EEModel/tree/v1.03>



# Linked & executable code & data



Starting repository: mbcxqcw2/EEModel/master  
New to Binder? Check out the [Binder Documentation](#) for more information.

Build logs

show

Here's a non-interactive preview on nbviewer while we start a server for you. Your binder will open automatically when it is ready.



JUPYTER FAQ

EEModel	master
Name	
◀ mbcxqcw2's repositories	
host_galaxies	
lin_mp_files	
ExcessElectronModel.ipynb	
ExcessElectronLib.py	
FRBcat_FRB_DMs.csv	
README.md	
cosmo_consts.py	
linear_growth_factor.py	
requirements.txt	
runtime.txt	

## Reproducibility Spectrum



```
jupyter ExcessElectronModel (unsaved changes)
File Edit View Insert Cell Kernel Widgets Help Not Trusted Python 2
In [1]: %reset
%matplotlib inline
print "Done."

Once deleted, variables cannot be recovered. Proceed (y/[n])? y
/home/charlie/anaconda2/lib/python2.7/site-packages/matplotlib/font_manager.py:273: UserWarning: Matplotlib is building the font cache using fc-list. This may take a moment.
warnings.warn('Matplotlib is building the font cache using fc-list. This may take a moment.')
Done.

Imports

In [2]: #standard imports
import numpy as np
from matplotlib import pyplot as plt
from scipy.interpolate import interp1d as ild

#other imports
from linear_growth_factor import E
#from WMB_scratch import Plognormal
from ExcessElectronLib import Prob_IGM # IGM distribution
from ExcessElectronLib import Convolve # Convolution function
from ExcessElectronLib import NormConv as Normalise # Normalisation function for P(DM|z)
from ExcessElectronLib import NormTranspose # Normalisation function for P(z|DM)
from ExcessElectronLib import find_nearest # function to find nearest value in discrete array to specified value
from ExcessElectronLib import FindErrorRange # function to find min/max bounds for a PDF

print 'Imports done.'
Imports done.

Import Host Galaxy Distributions

In [3]: #####
###Stellar distributed FRBs in spirals###
#####

##OB STARS##
print "OB..."
OB_data=np.loadtxt('./host_galaxies/OB_FRBs_list.txt')
OB_DMs = zip(*np.array(OB_data))[0][:]

##YOUNG PULSARS##
print "YPSR..."
YPSR_data=np.loadtxt('./host_galaxies/young_FRBs_list.txt')
YPSR_DMs = zip(*np.array(YPSR_data))[0][:]

##OLD PULSARS##
print "OPSR..."
OPSR_data=np.loadtxt('./host_galaxies/old_FRBs_list.txt')
OPSR_DMs = zip(*np.array(OPSR_data))[0][:]

##MSPS##
print "MSP..."
MSP_data=np.loadtxt('./host_galaxies/msp_FRBs_list.txt')
MSP_DMs = zip(*np.array(MSP_data))[0][:]

"""
#Note: these are commented out to prevent importing huge numbers of files.
#####
#Homogenously distributed FRBs in spirals#
#####
```



# Impact































- 4 April 2018:
  - Submitted manuscript to journal
  - Deposited preprint to arXiv
- 9 April 2018: Received referee report!
- 10 citations to date even though it is not officially published by the journal yet

<https://ui.adsabs.harvard.edu/abs/2018arXiv180401548W/citations>

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	<a href="#">The prevalence of repeating fast radio bursts</a>		
	Ravi, Vikram		
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	Ravi, Vikram; Battaglia, Nicholas; Burke-Spolaor, Sarah <a href="#">and 13 more</a>		
7	2019ApJ...872...88R	2019/02	  
	<a href="#">Measuring the Circumgalactic and Intergalactic Baryon Contents with Fast Radio Bursts</a>		
	Ravi, Vikram		
8	2018MNRAS.480.3907V	2018/11	  
	<a href="#">Probing the origin of extragalactic magnetic fields with Fast Radio Bursts</a>		
	Vazza, F.; Brüggen, M.; Hinz, P. M. <a href="#">and 3 more</a>		
9	2018ApJ...867L..10M	2018/11	  
	<a href="#">A Search for the Host Galaxy of FRB 171020</a>		
	Mahony, Elizabeth K.; Ekers, Ron D.; Macquart, Jean-Pierre <a href="#">and 11 more</a>		
10	2018PhRvD..98j3518M	2018/11	  
	<a href="#">Finding the missing baryons with fast radio bursts and Sunyaev-Zeldovich maps</a>		
	Muñoz, Julian B.; Loeb, Abraham		



# Takeaways

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- “Reproducibility is like brushing your teeth. It is good for you, but it takes time and effort. Once you learn it, it becomes a habit.”  
- Irakli Loladze (<https://doi.org/10.1038/533452a>)
- Start small! Test out one platform or open up one stage of your research workflow, such as sharing data via Zenodo & linking to the DOI in your publications.
- Check out *The Turing Way* - a handbook on reproducible research/ data science openly developed at <https://github.com/alan-turing-institute/the-turing-way/>
- TEDx talk: Research Culture is Broken; Open Science can [help] fix it <https://youtu.be/c-bemNZ-lqA>
- Get in touch! Email: [rachael.ainsworth@manchester.ac.uk](mailto:rachael.ainsworth@manchester.ac.uk)

