# Reproducibility and Open Science

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

@rachaelevelyn
@rainsworth
10.6084/m9.figshare.10255727

# Outline

- 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

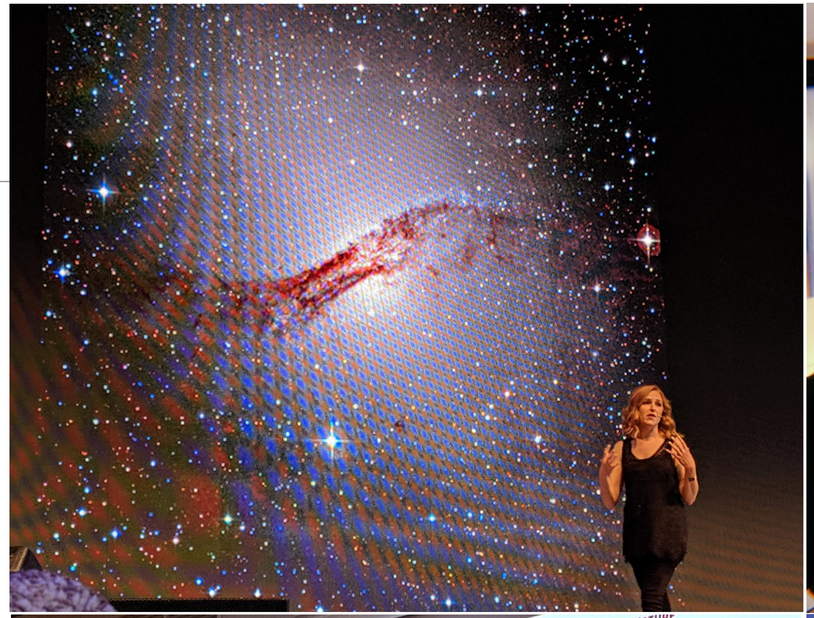
# About me and my Open Science journey

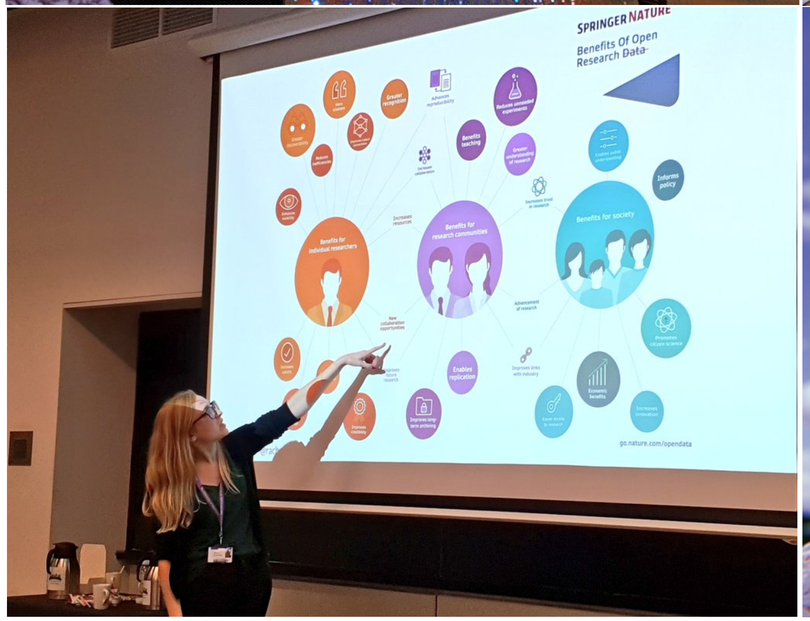
# About me

- 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




# My career path and Open Science journey

BSc Physics

University of Tennessee

- Interned at NASA's JPL

2005-2010

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BSc Physics

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2010-2014

PhD Astrophysics

Trinity College Dublin

Dublin Institute for Advanced Studies

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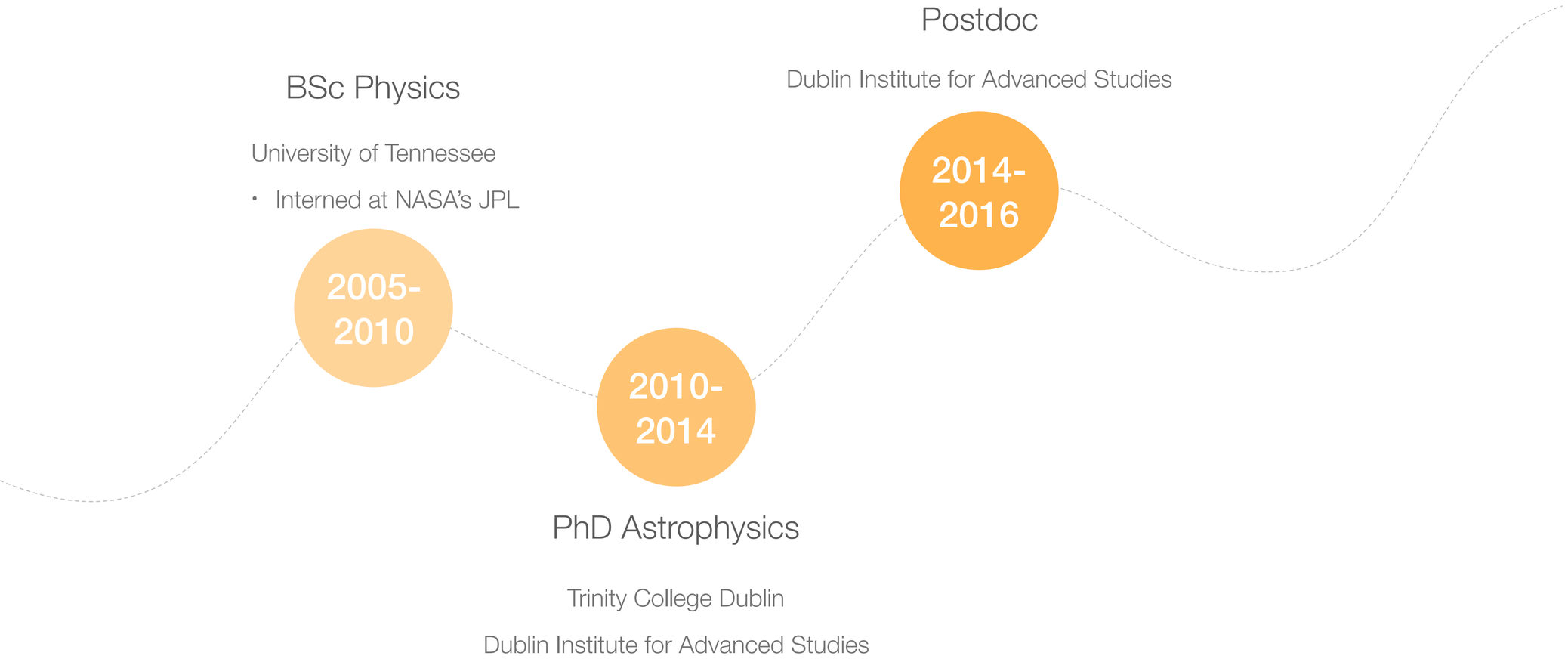


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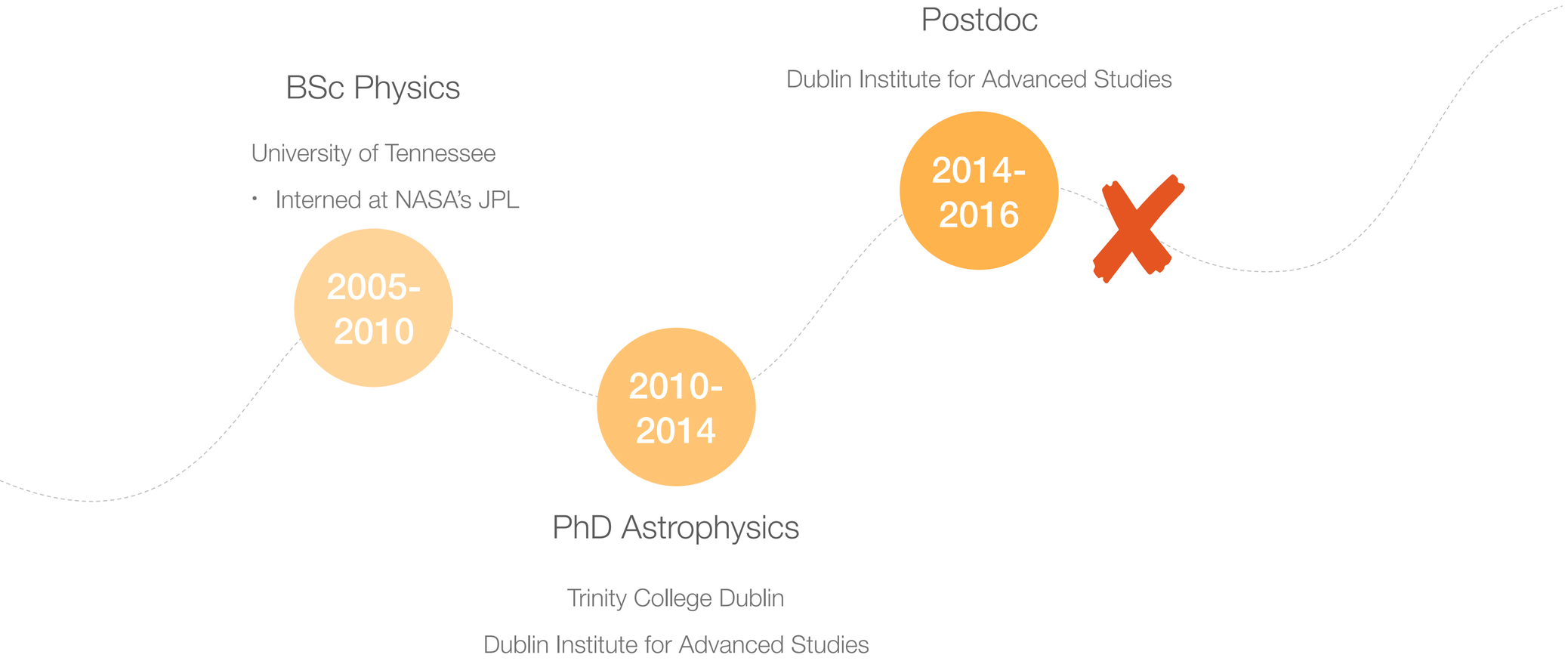


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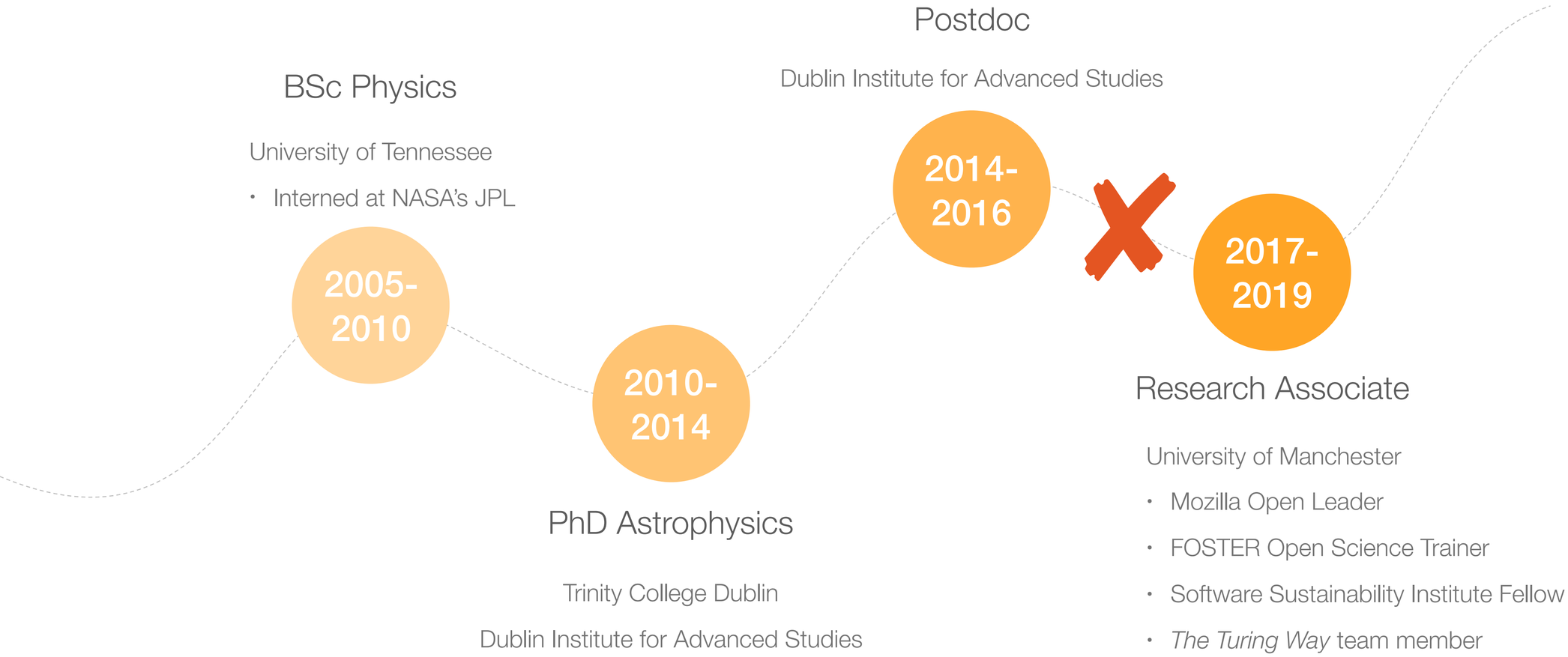


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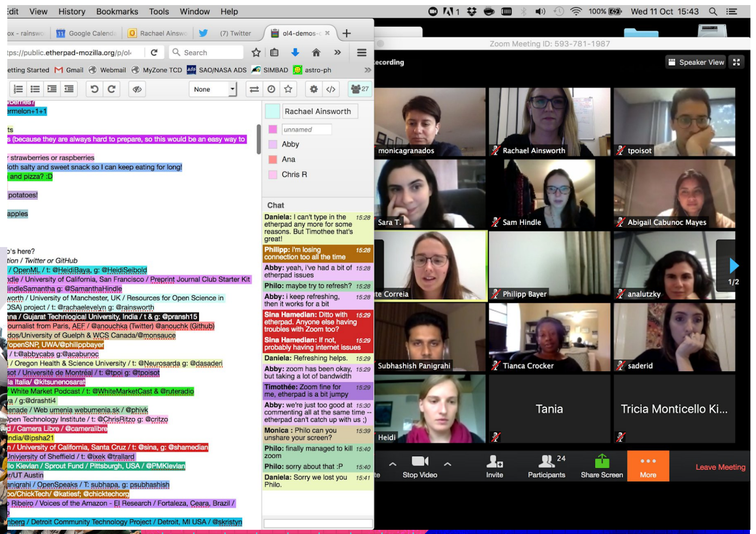
# Open Science Advocacy

- 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

Software Sustainability Institute



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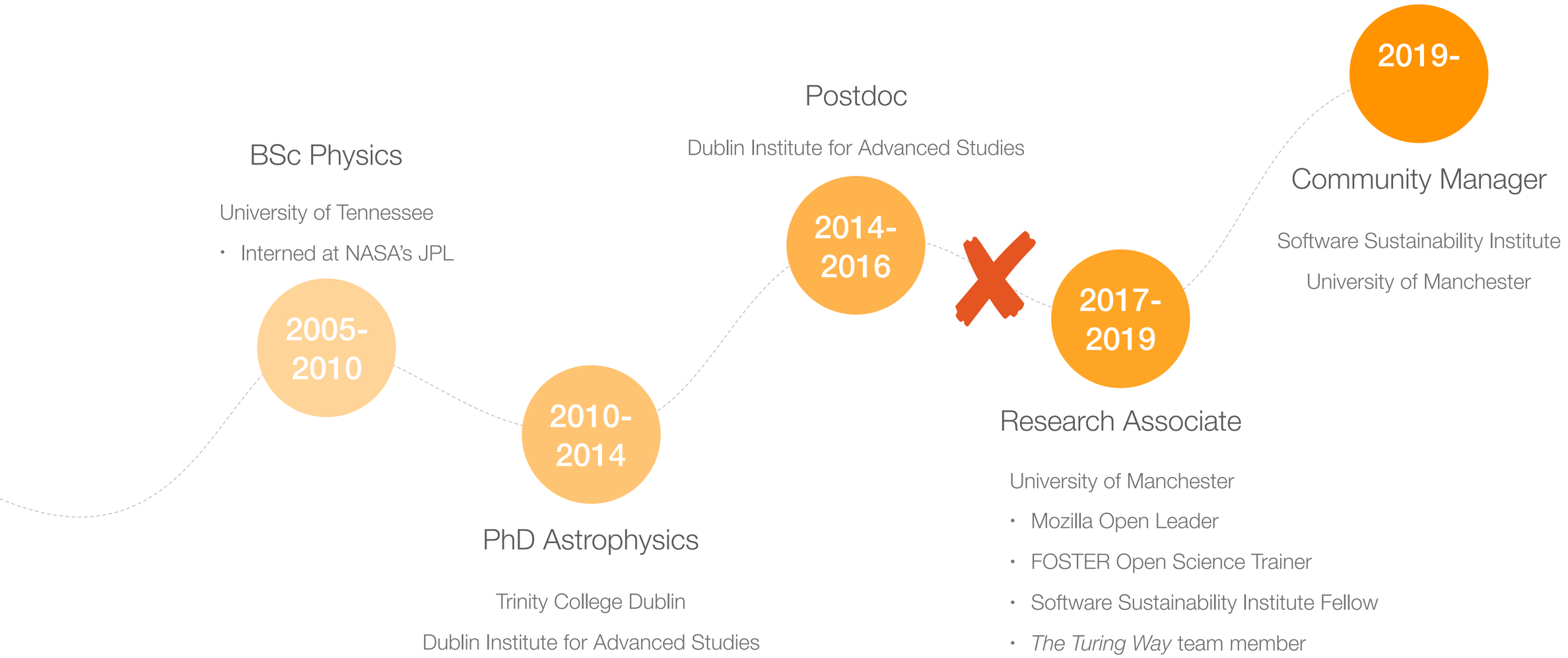
# Research Culture is Broken; Open Science can [help] Fix It

https://youtu.be/c-bemNZ-IqA

# My career path and Open Science journey

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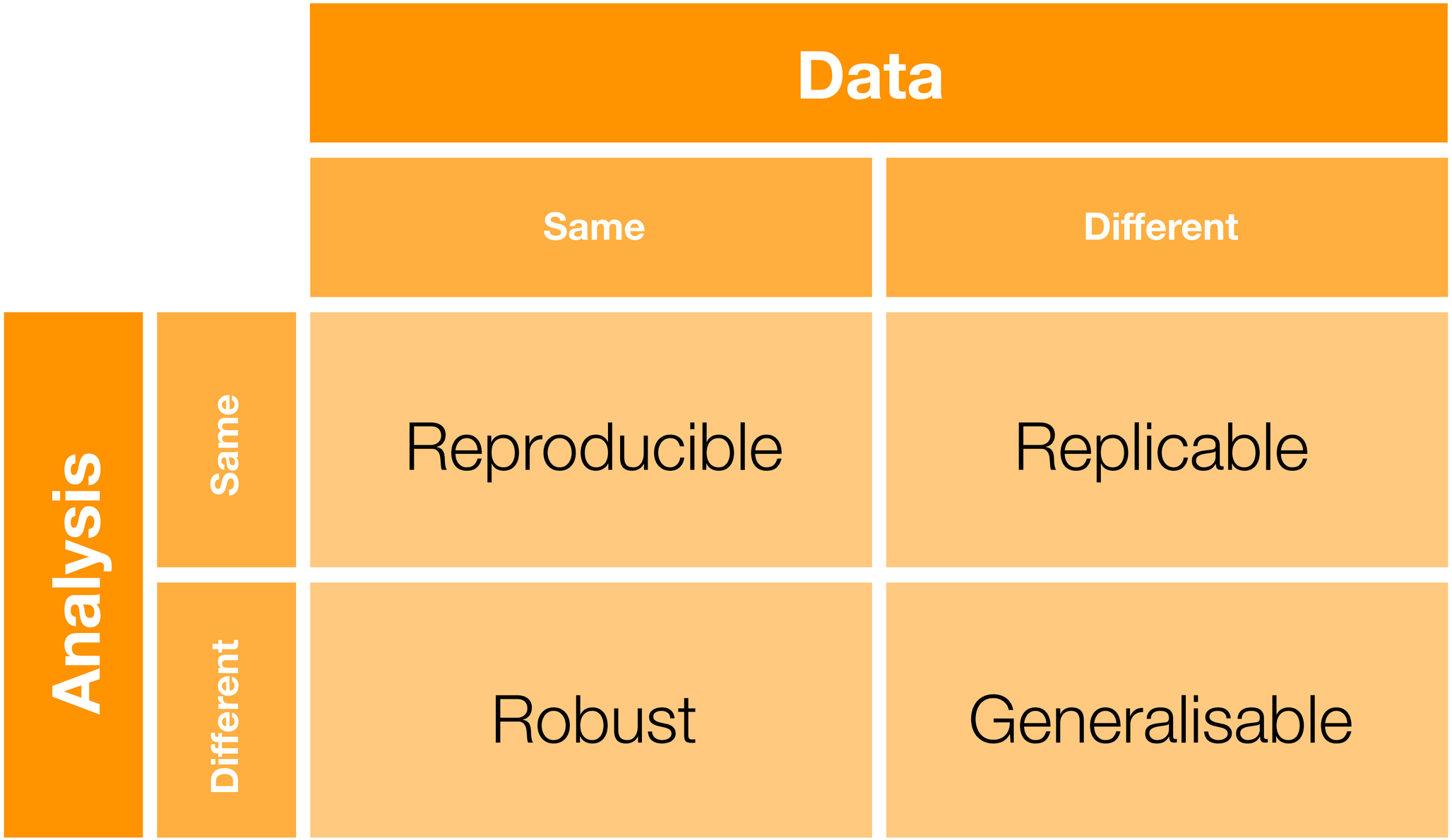
# Reproducibility and research culture




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

nature International weekly journal of science



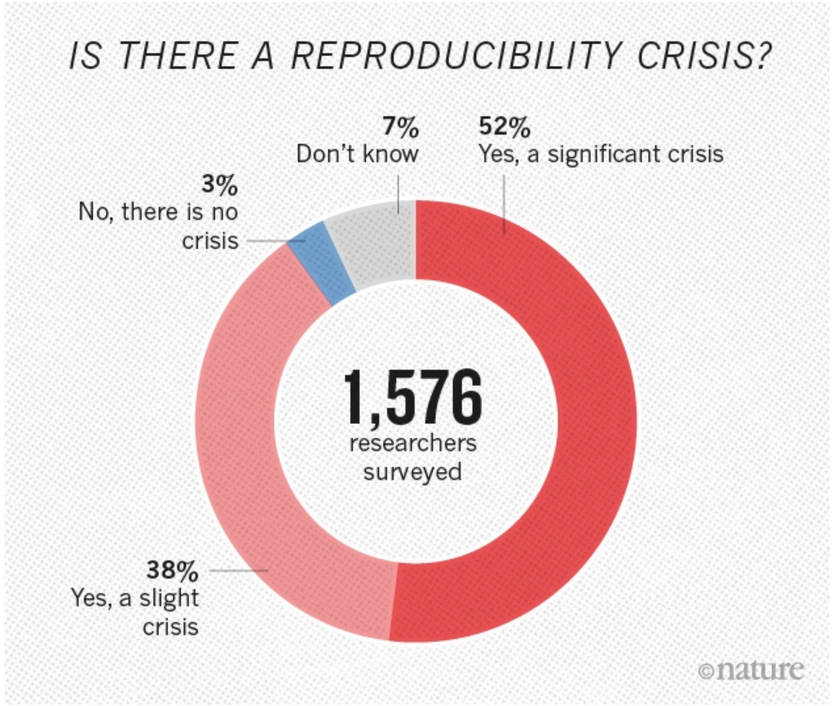
*NATURE* | NEWS FEATURE

# 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

nature International weekly journal of science

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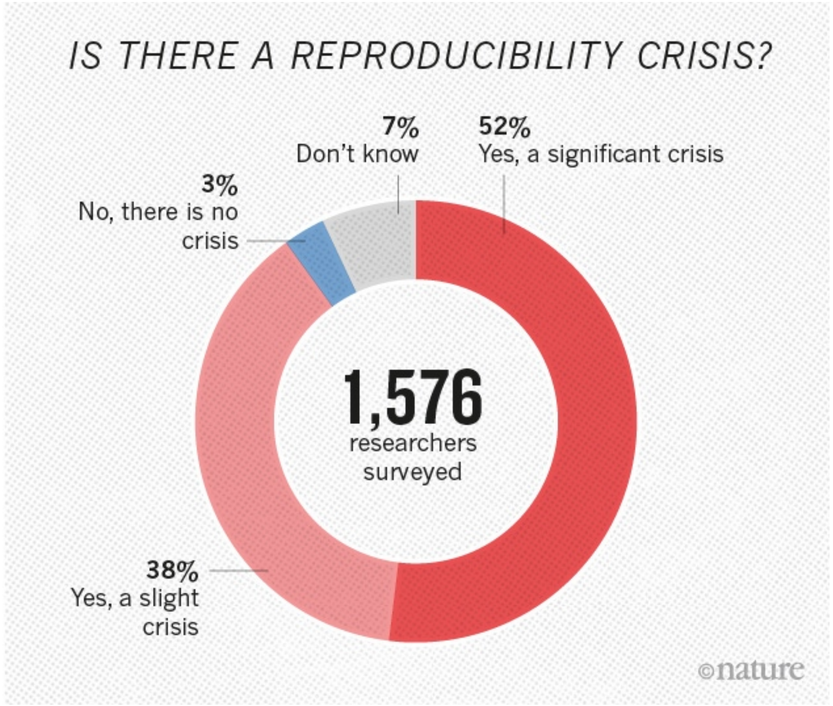


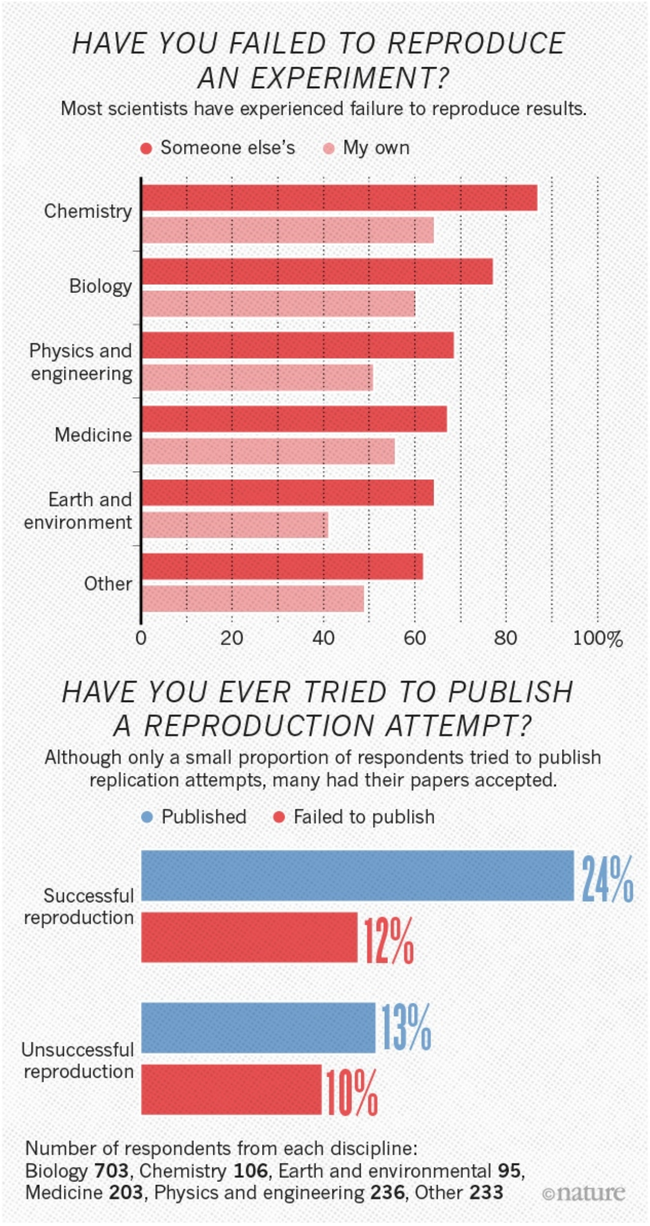


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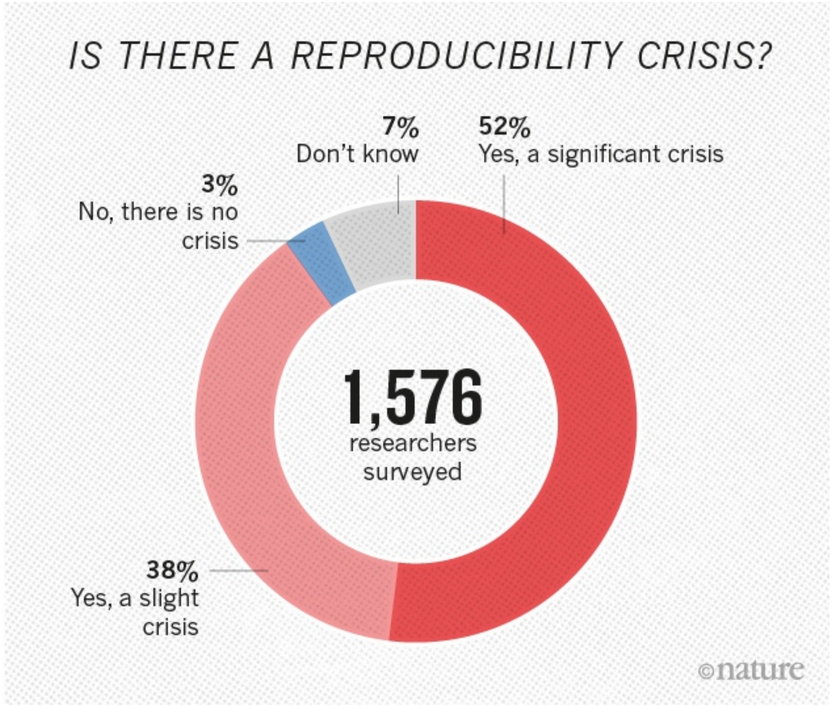


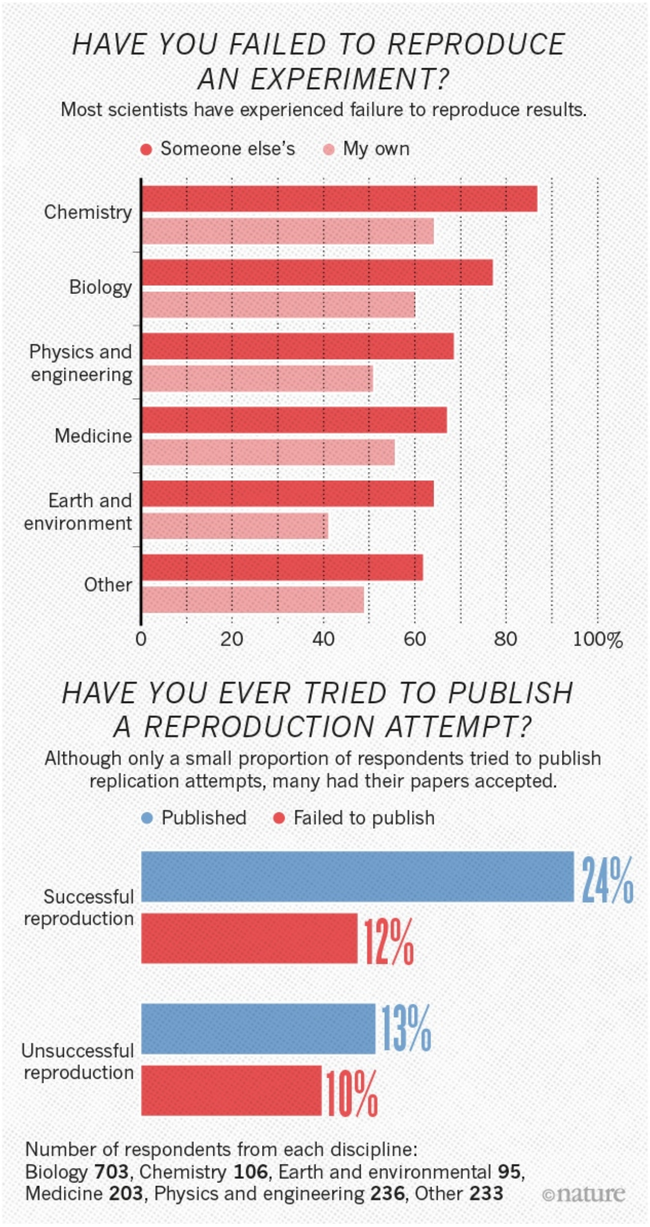


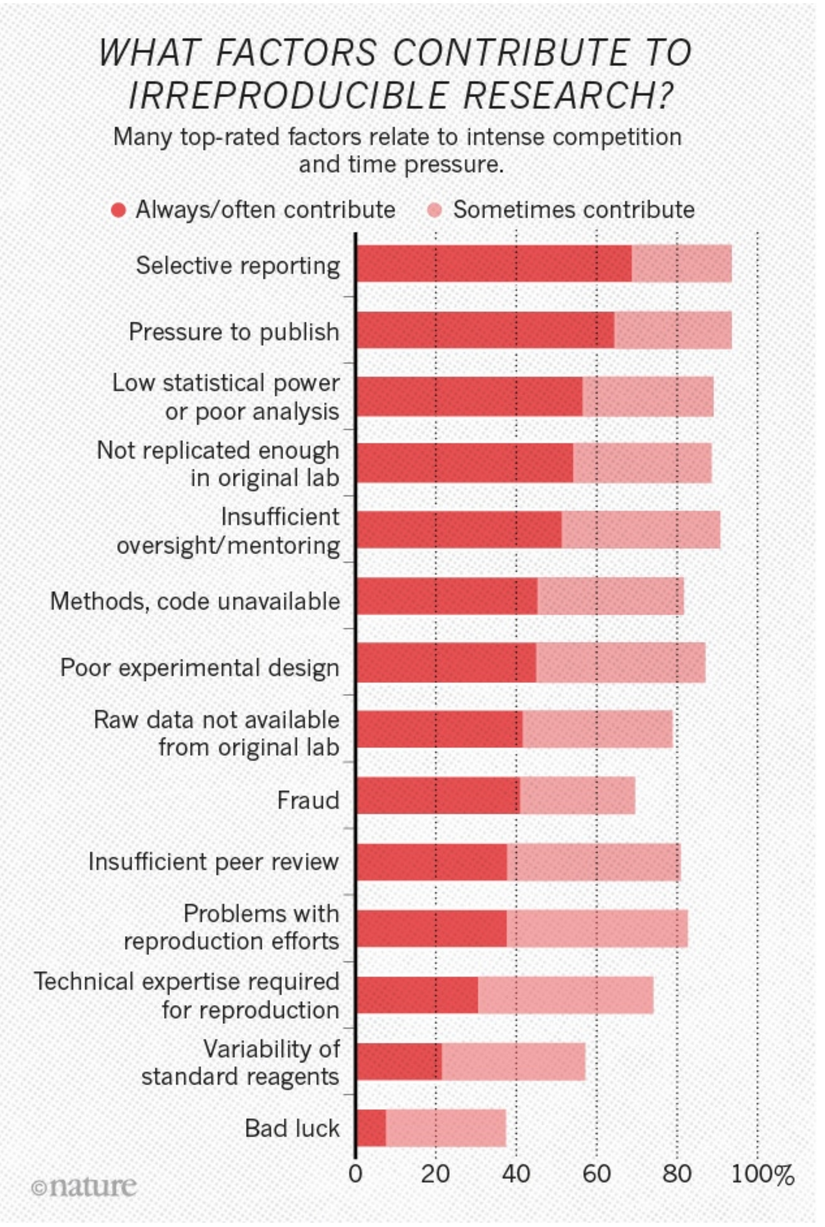


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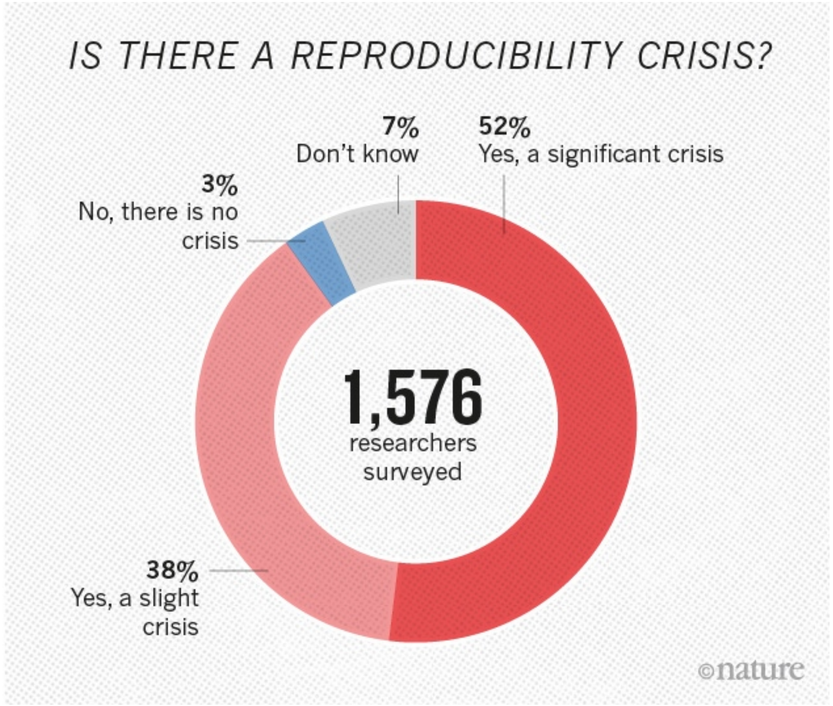


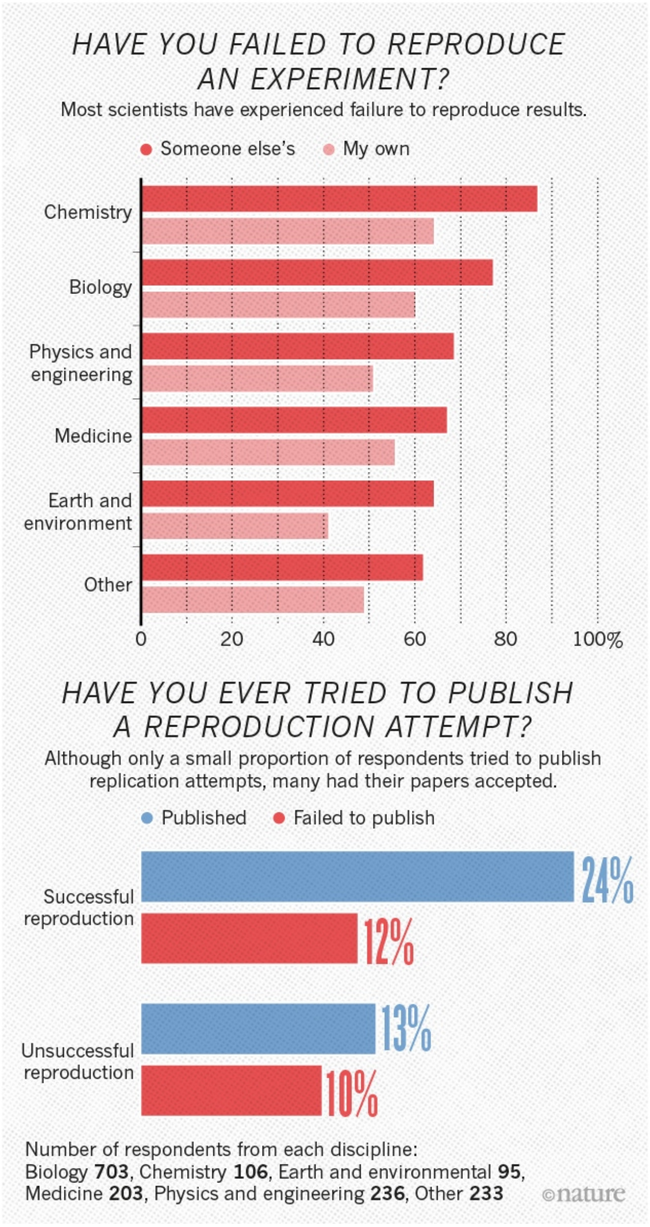


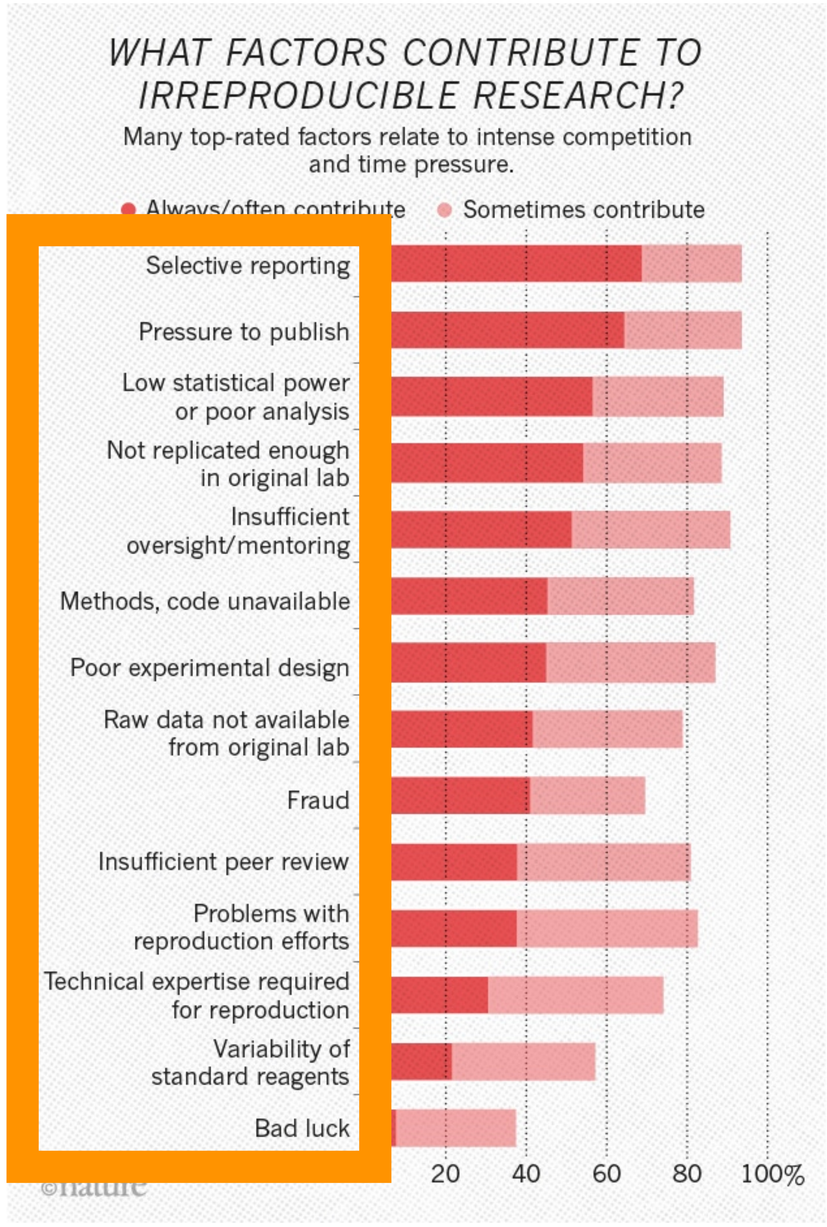


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NATURE | NEWS

# Sluggish data sharing hampers reproducibility effort

**Initiative trying to validate 50 cancer papers finds difficulty in accessing original study data.**

Richard Van Noorden

03 June 2015

**RIO DE JANEIRO, BRAZIL**



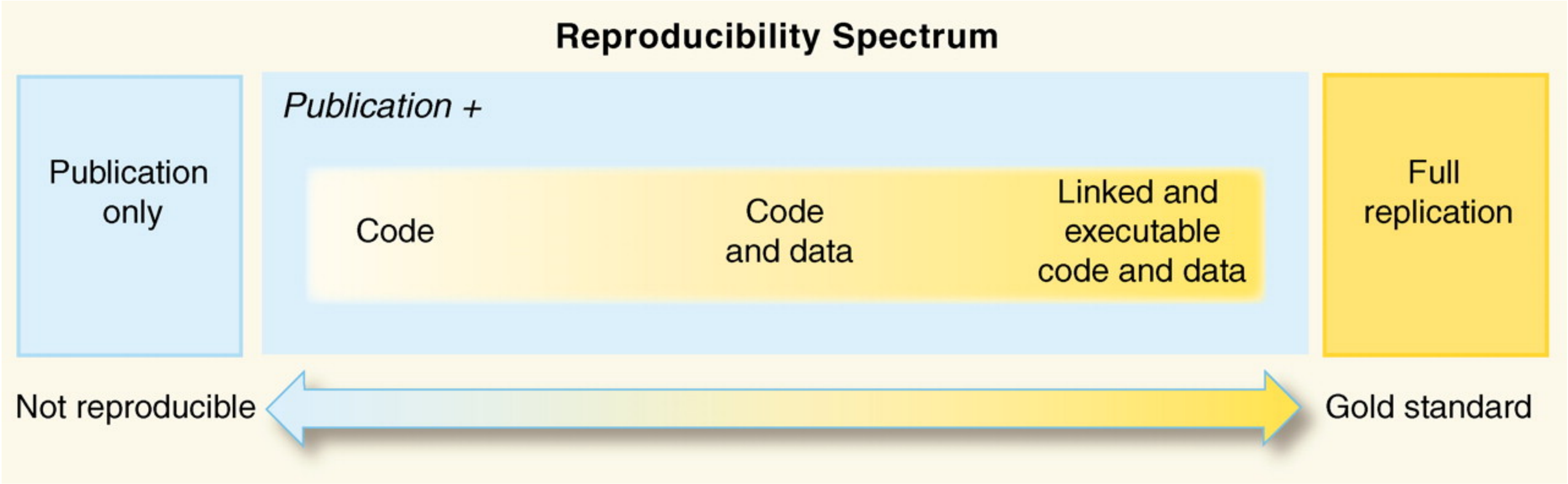
An initiative that aims to validate the findings of key cancer papers is being slowed by an unexpected hurdle — problems accessing data from the original studies.

The Reproducibility Initiative: Cancer Biology consortium aims to repeat experiments from 50 highly-cited studies published in 2010–12 in journals such as *Nature*, *Cell* and *Science*, to see how easy it is to reproduce their findings. Although these journals require authors to share their data on request, it has taken two months on average to get the data for each paper, said William Gunn, a co-leader of the project, at the 4th World Conference on Research Integrity in Rio de Janeiro, Brazil, on 3 June.

For one paper, securing the necessary data took a year. And the authors of four other papers have stopped communicating with the project altogether. In those instances, the journals that published the studies are stepping in to remind researchers of their responsibilities.



Van Noorden (2015) https://doi.org/10.1038/nature.2015.17694

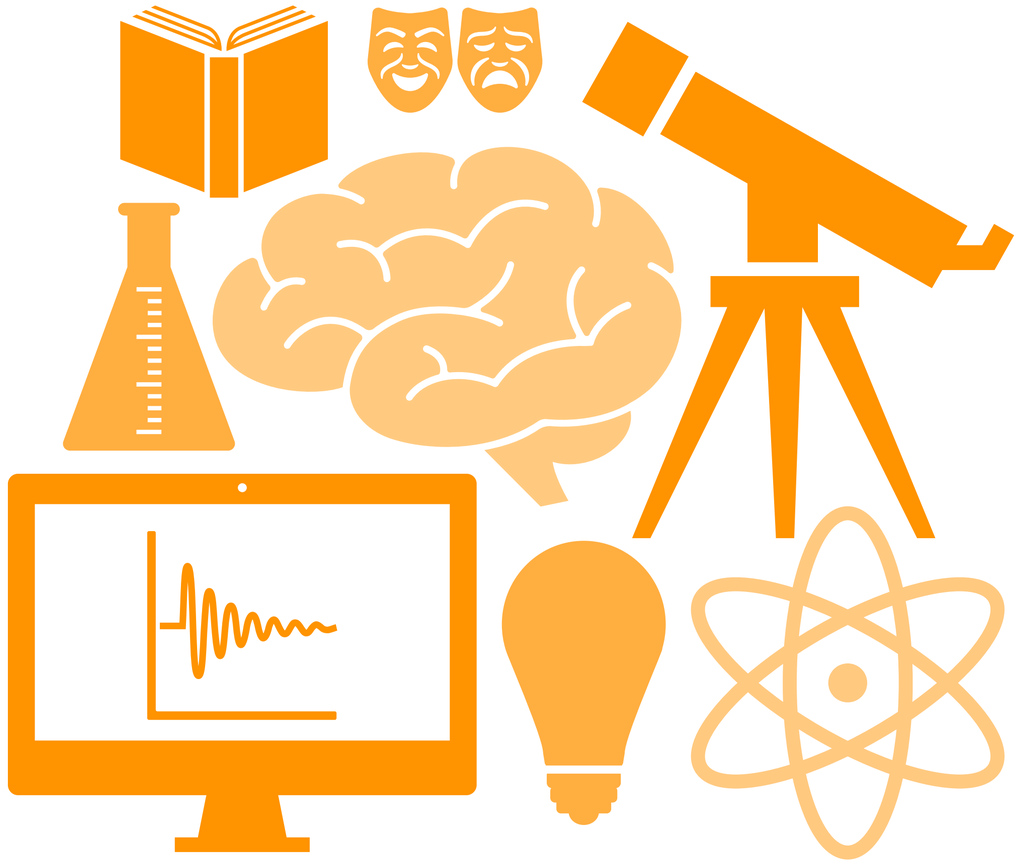



"Computational science has led to exciting new developments, but the nature of the work has exposed limitations in our ability to evaluate published findings. Reproducibility has the potential to serve as a minimum standard for judging scientific claims when full independent replication of a study is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

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

# Research Culture

- 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

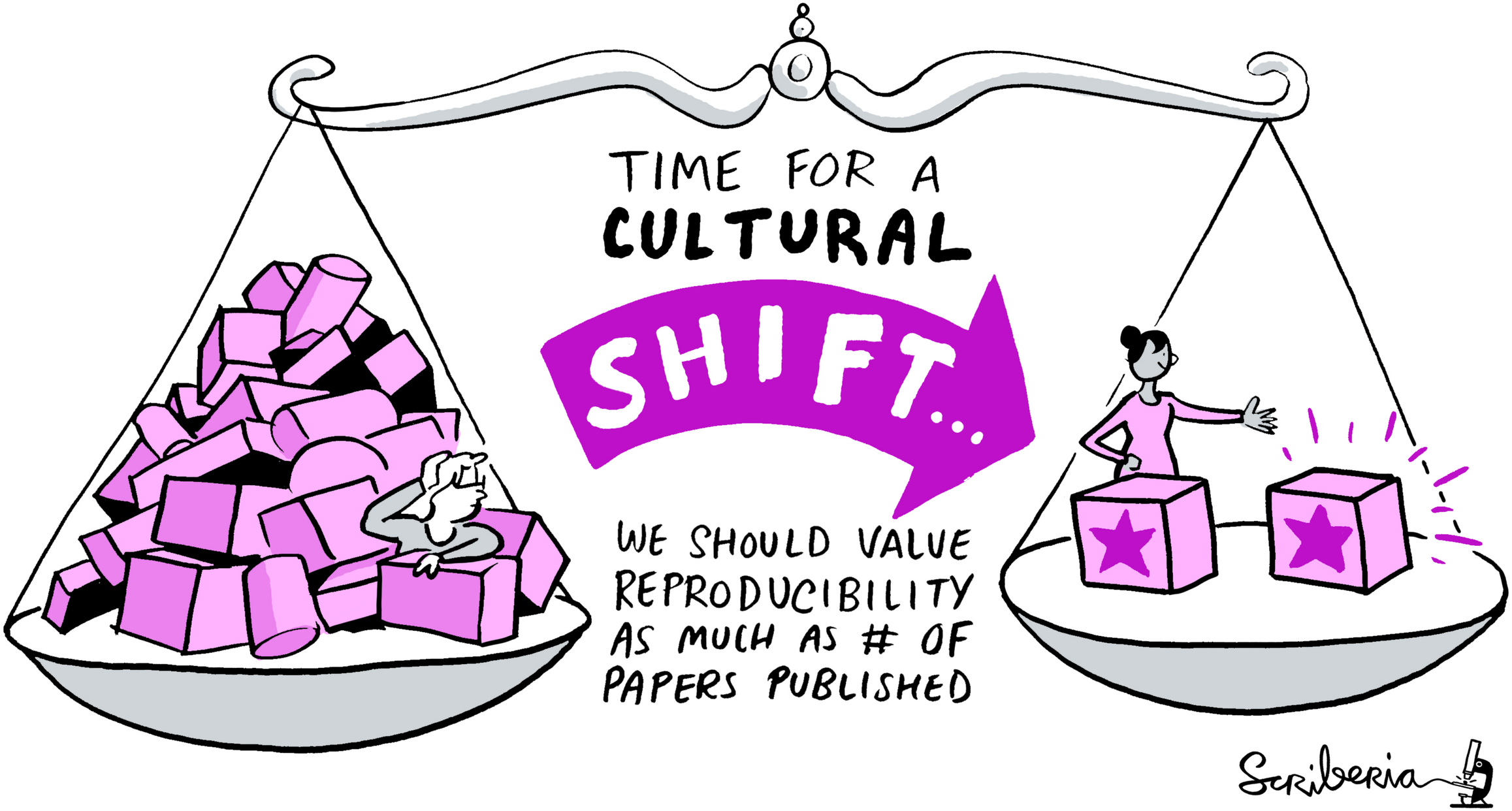
University believes new criteria rewarding selfless behaviour will ‘focus minds’

- 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

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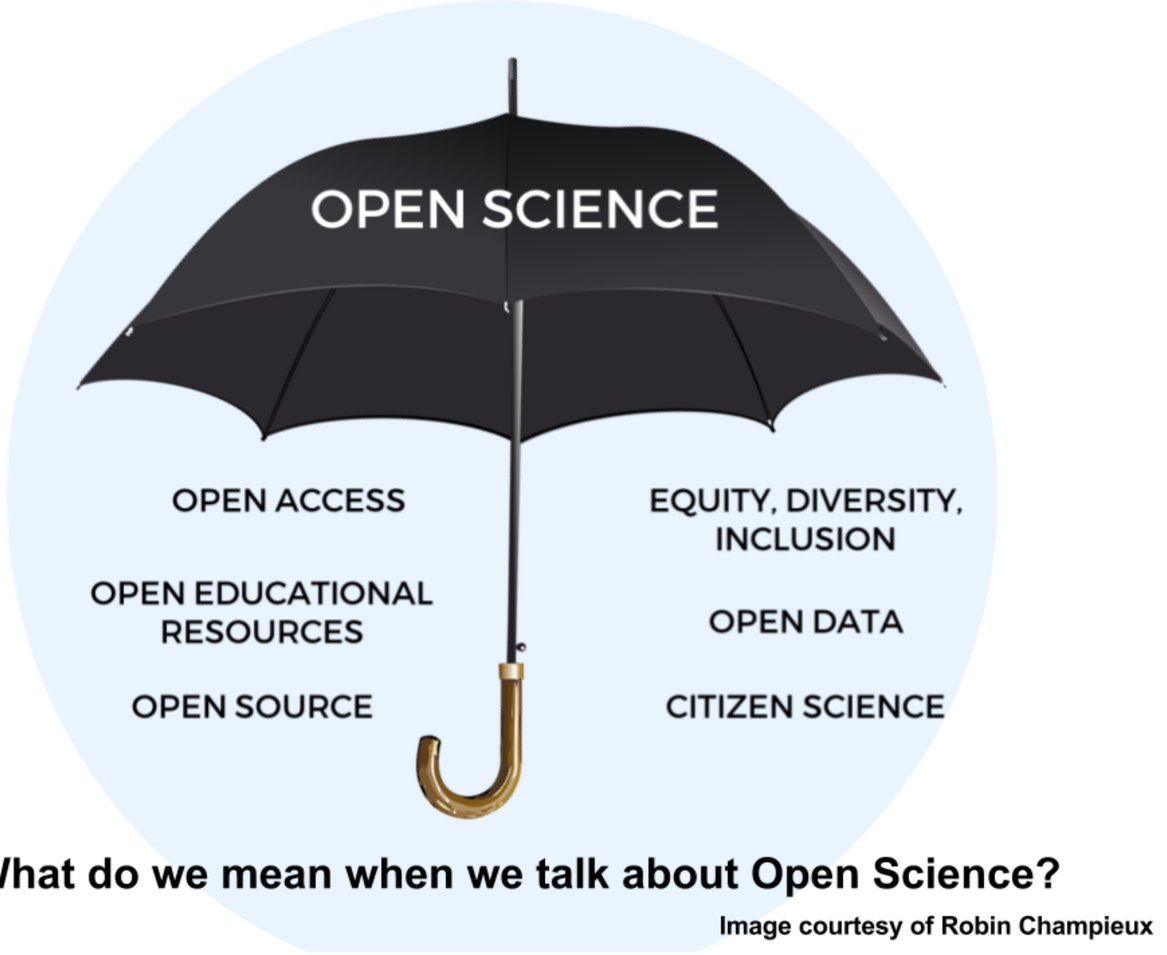
# Open Science / Research / Scholarship

# 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.




**What do we mean when we talk about Open Science?**

**Image courtesy of Robin Champieux**

(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

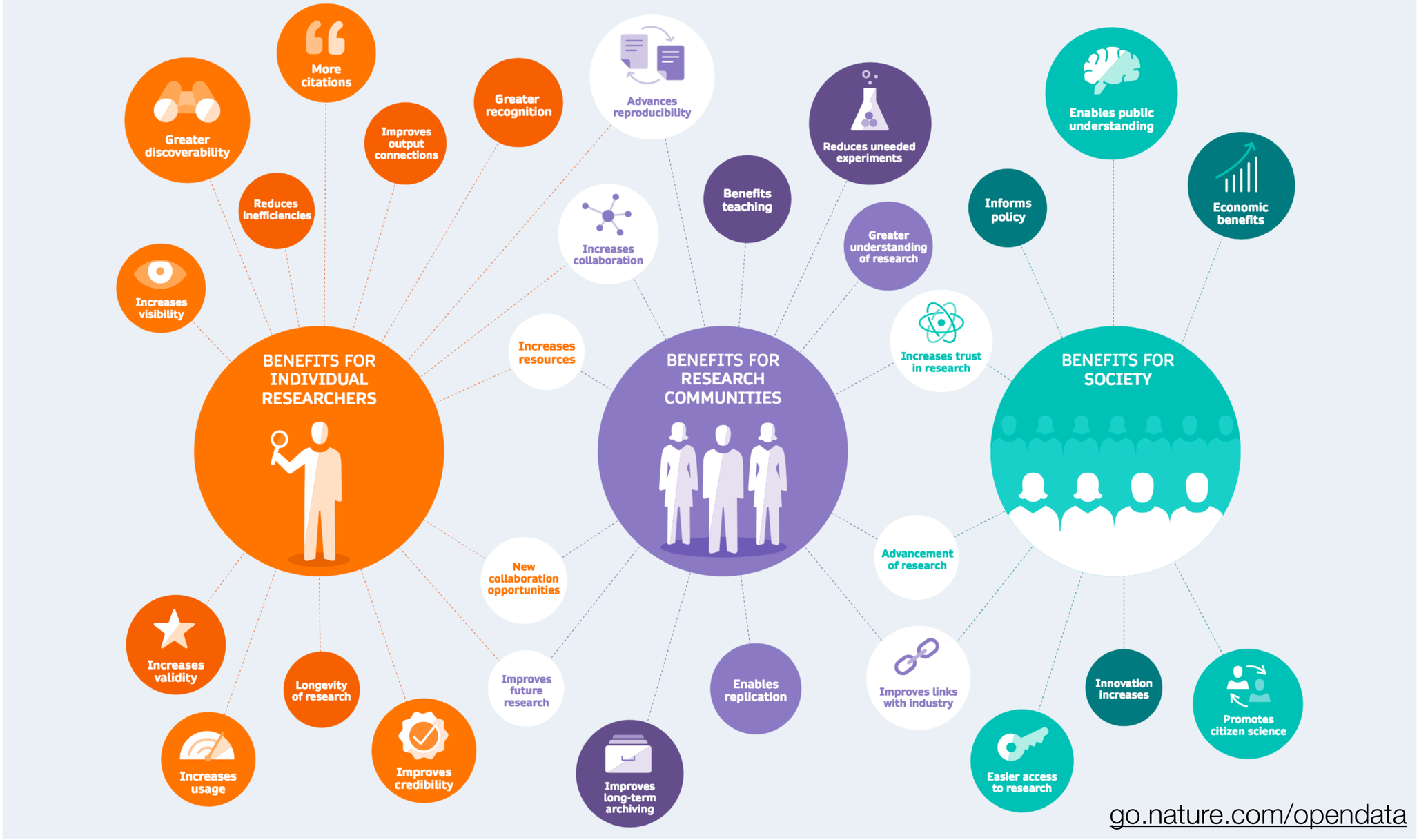
- Scooping or ideas being stolen
- Not being credited for ideas
- Errors and public humiliation
- Risk to reputation
- Reduced scientific quality
- Information overload


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

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

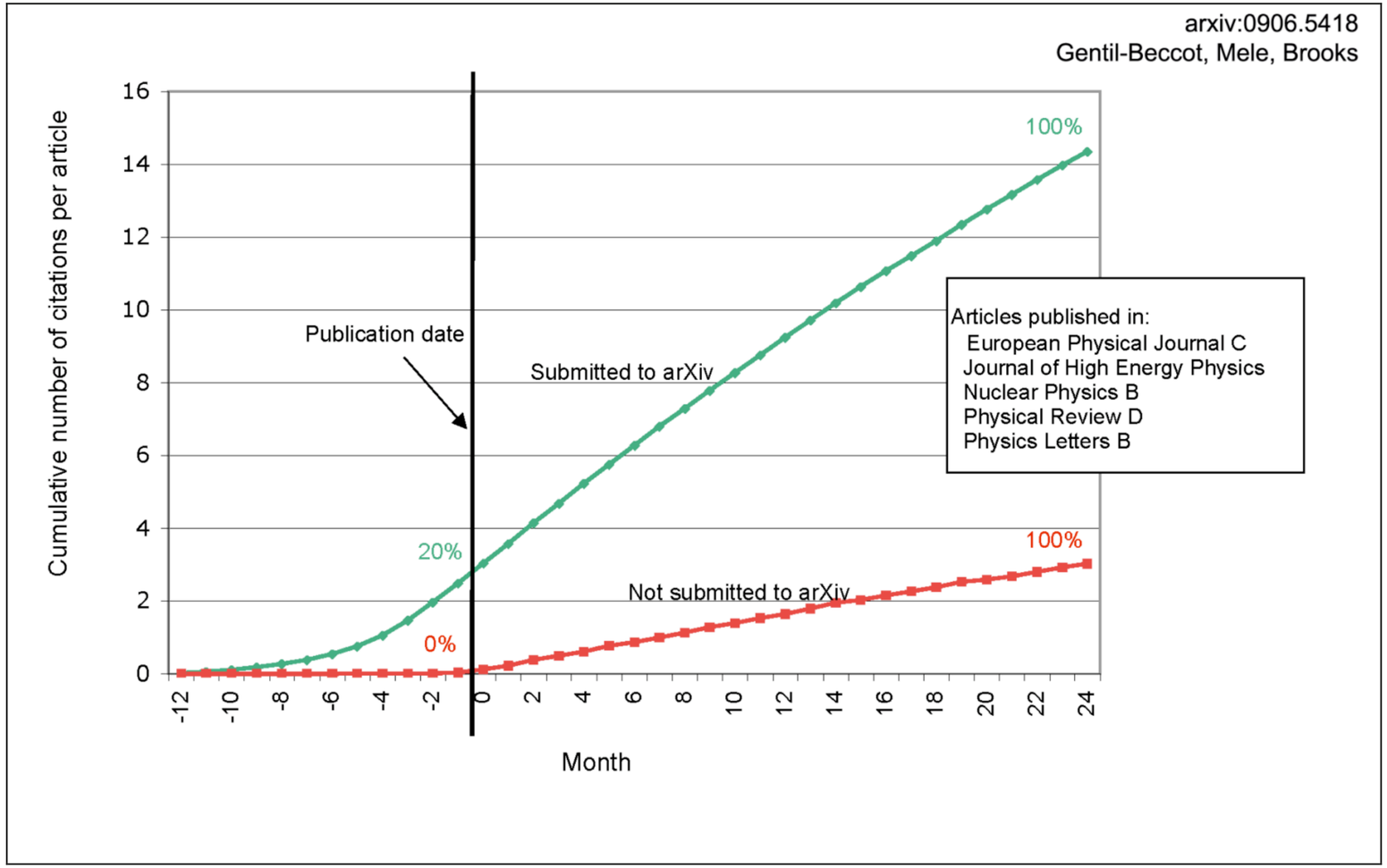
## Abstract

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**

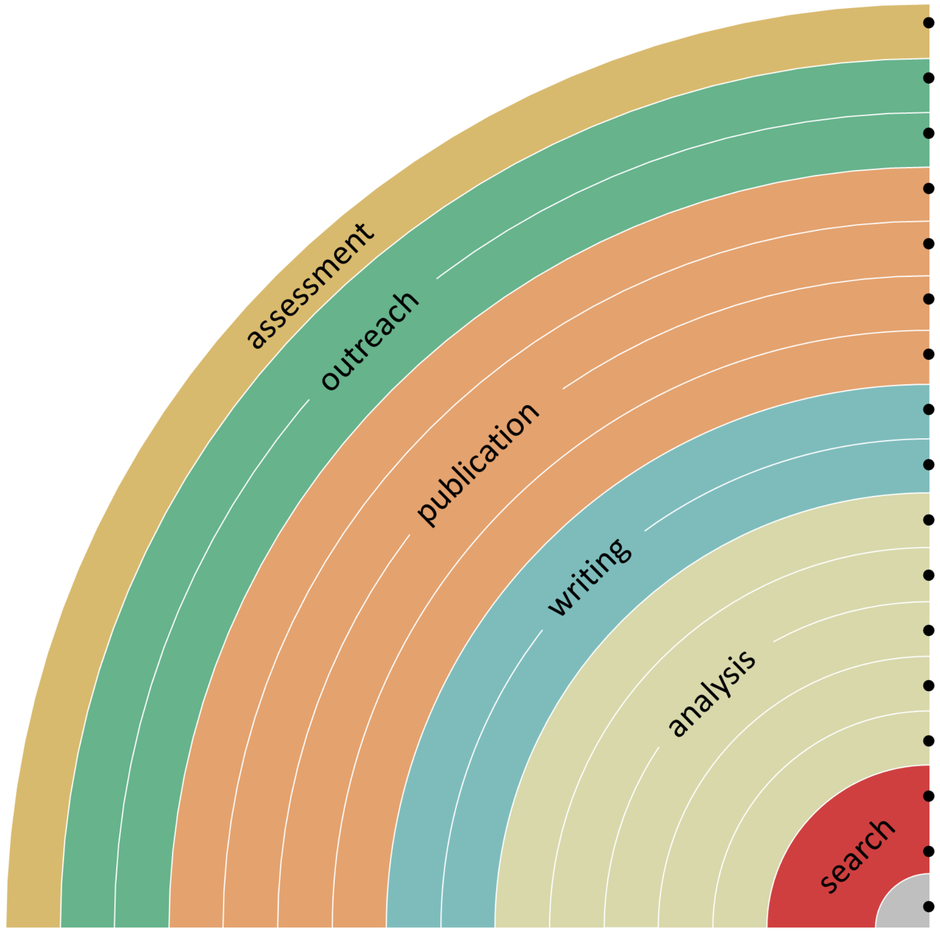
https://dynamicecology.wordpress.com/2015/02/18/the-biggest-benefit-of-my-shift-to-r-reproducibility/


**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

# How to open up your research workflow

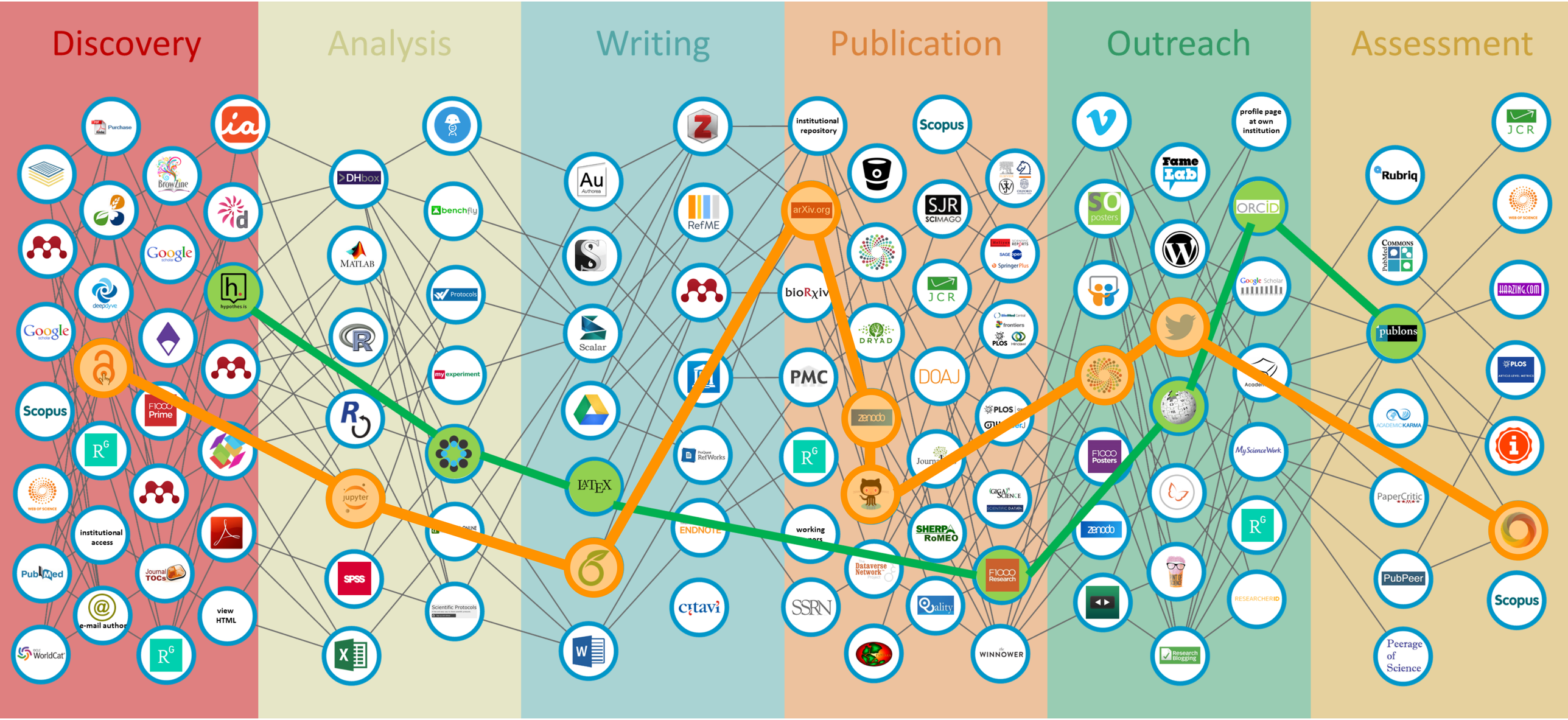
# You can make your workflow more open by…




- 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



DOI: 10.5281/zenodo.1147025




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

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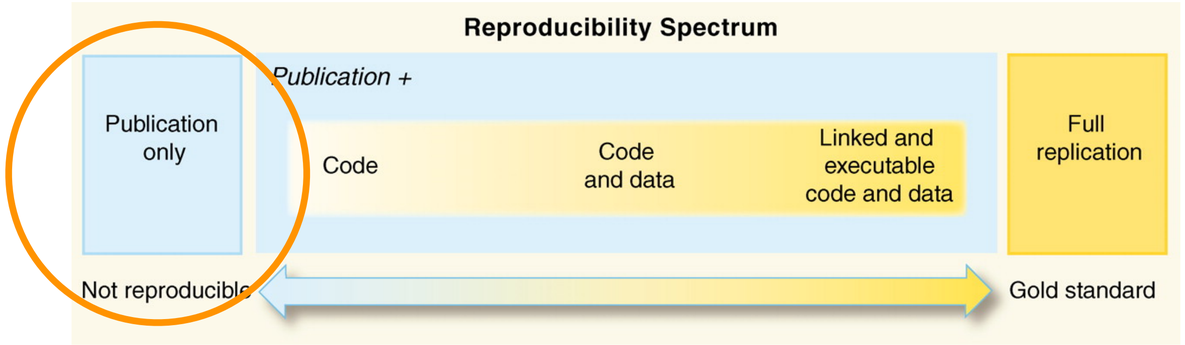
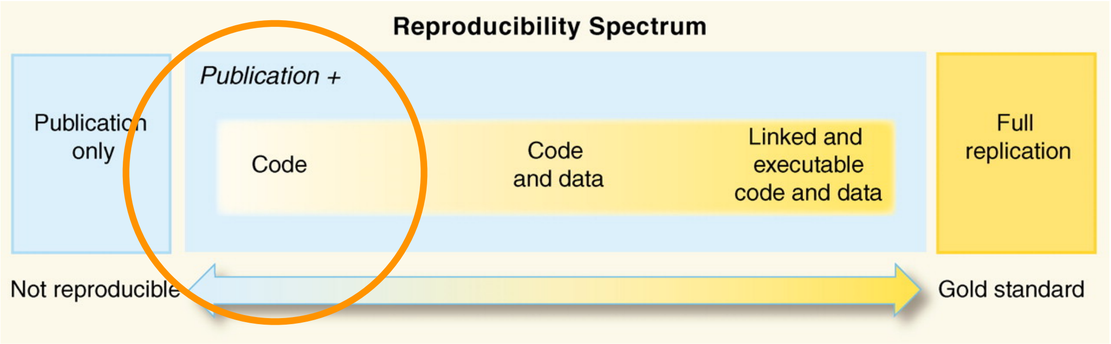
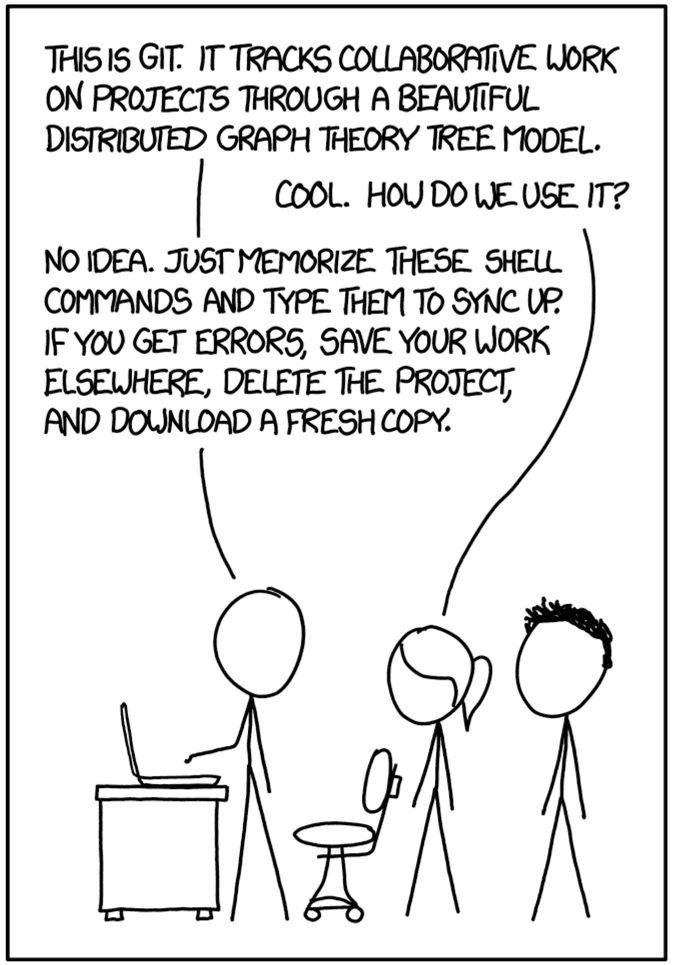


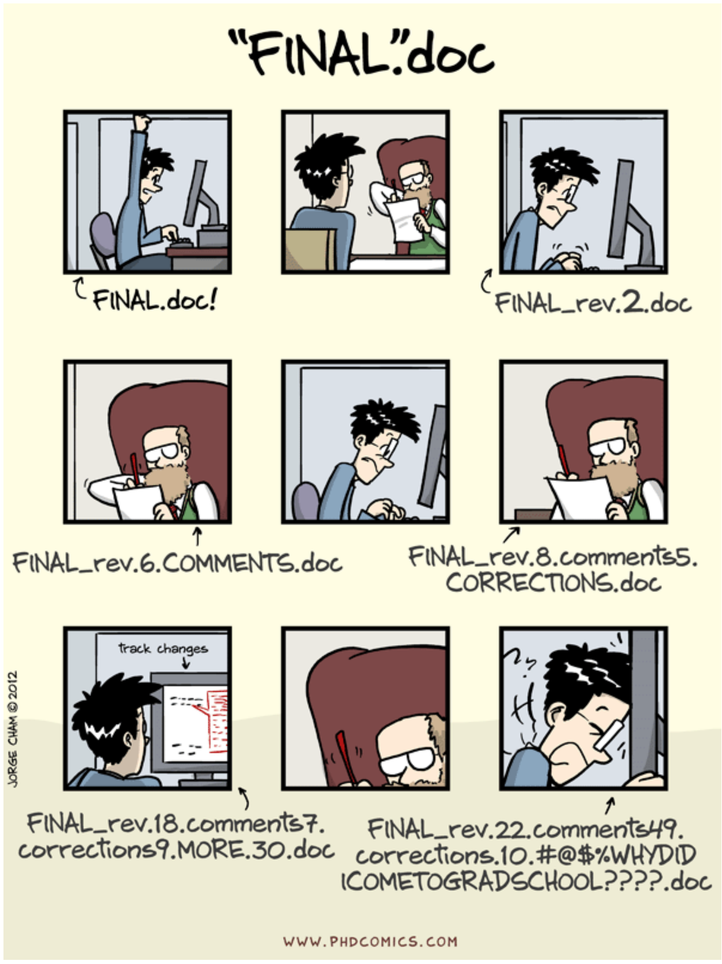

Jeroen Bosman and Bianca Kramer - https://101innovations.wordpress.com

# 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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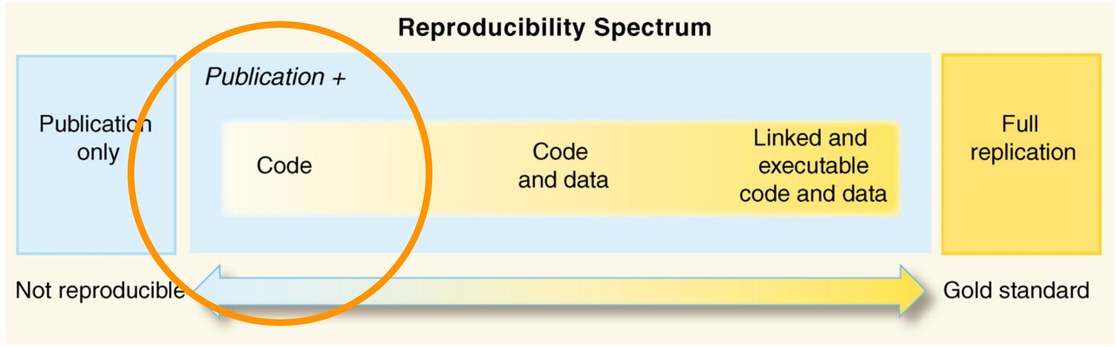
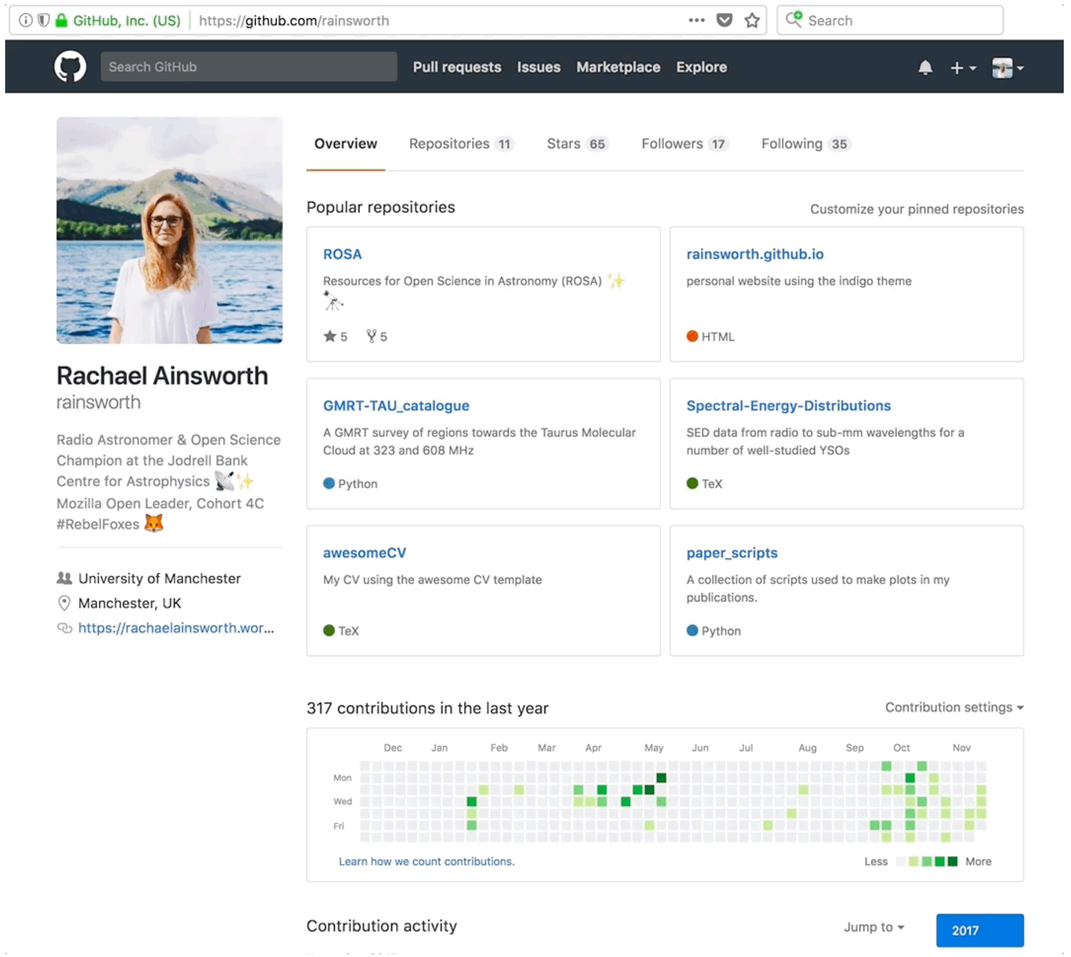
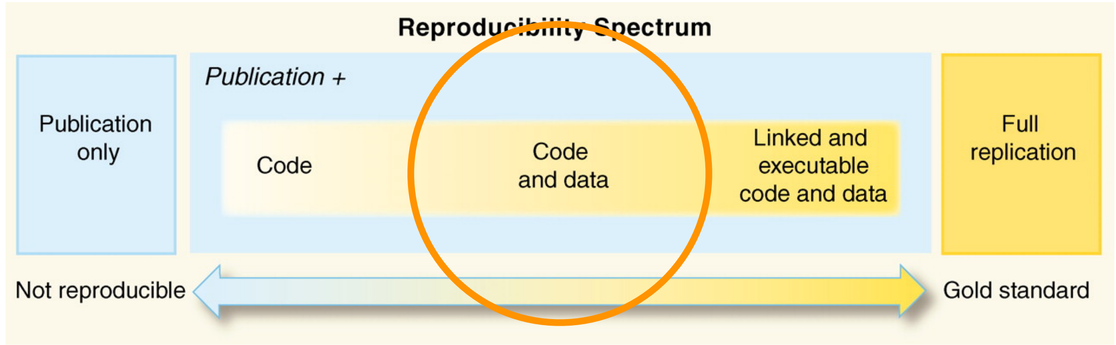


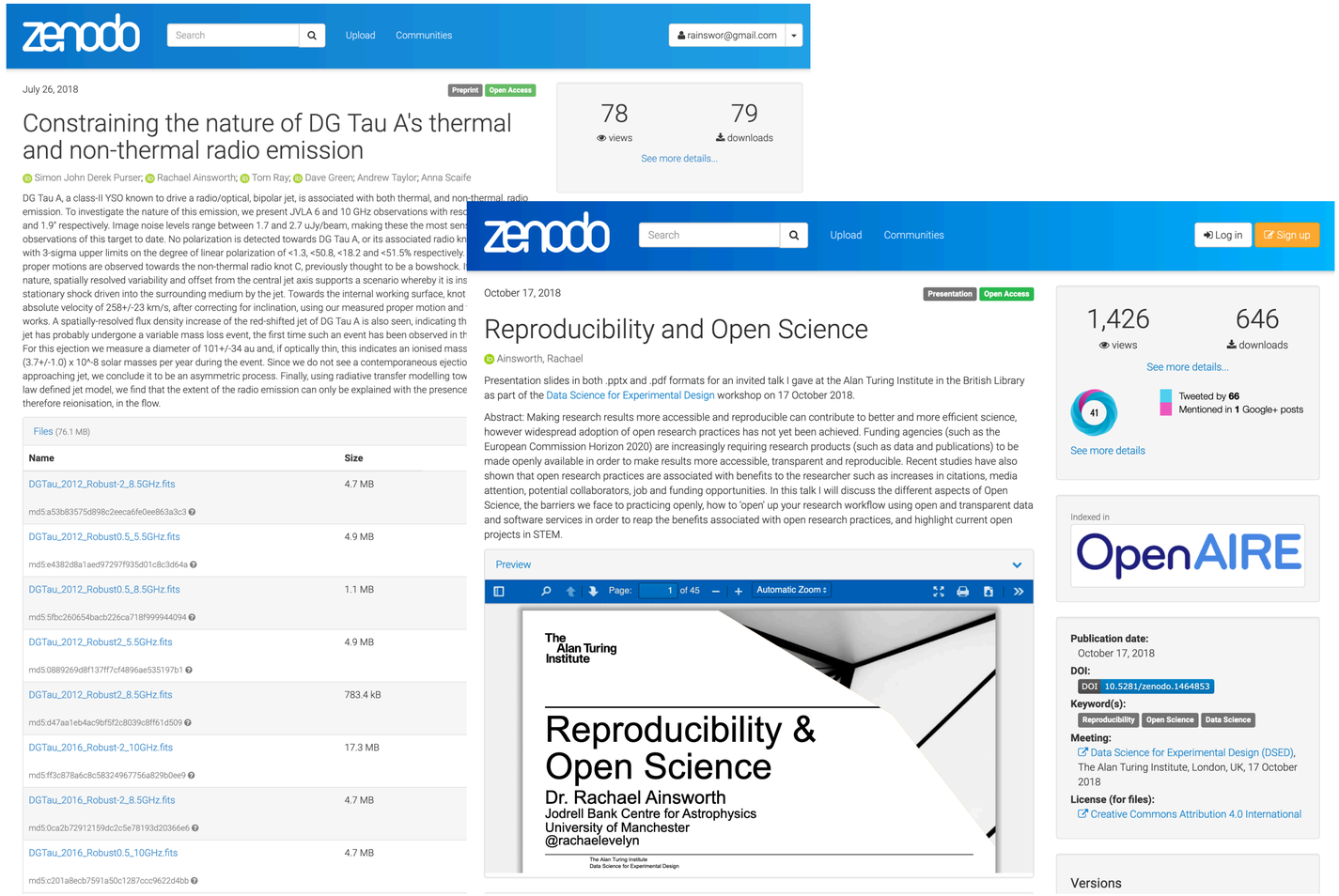



# Share research outputs in Open Repositories such as Figshare, Zenodo & the OSF

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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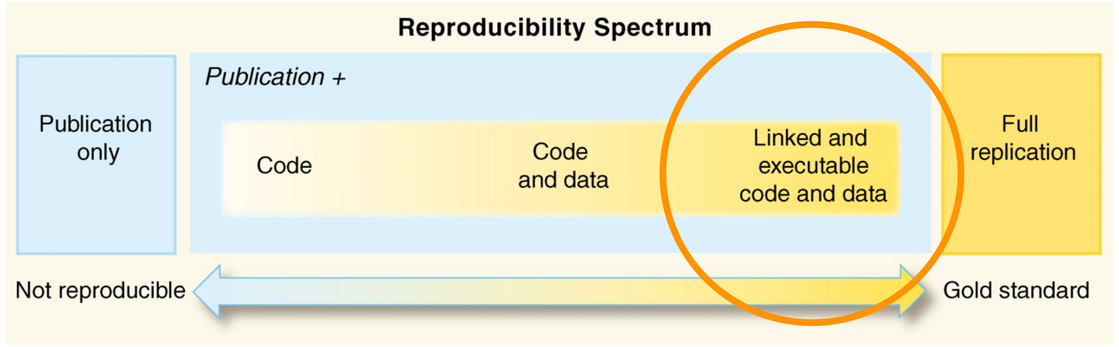
https://doi.org/10.6084/m9.figshare.10255727

# Share analyses using Open Notebooks such as Jupyter & RStudio

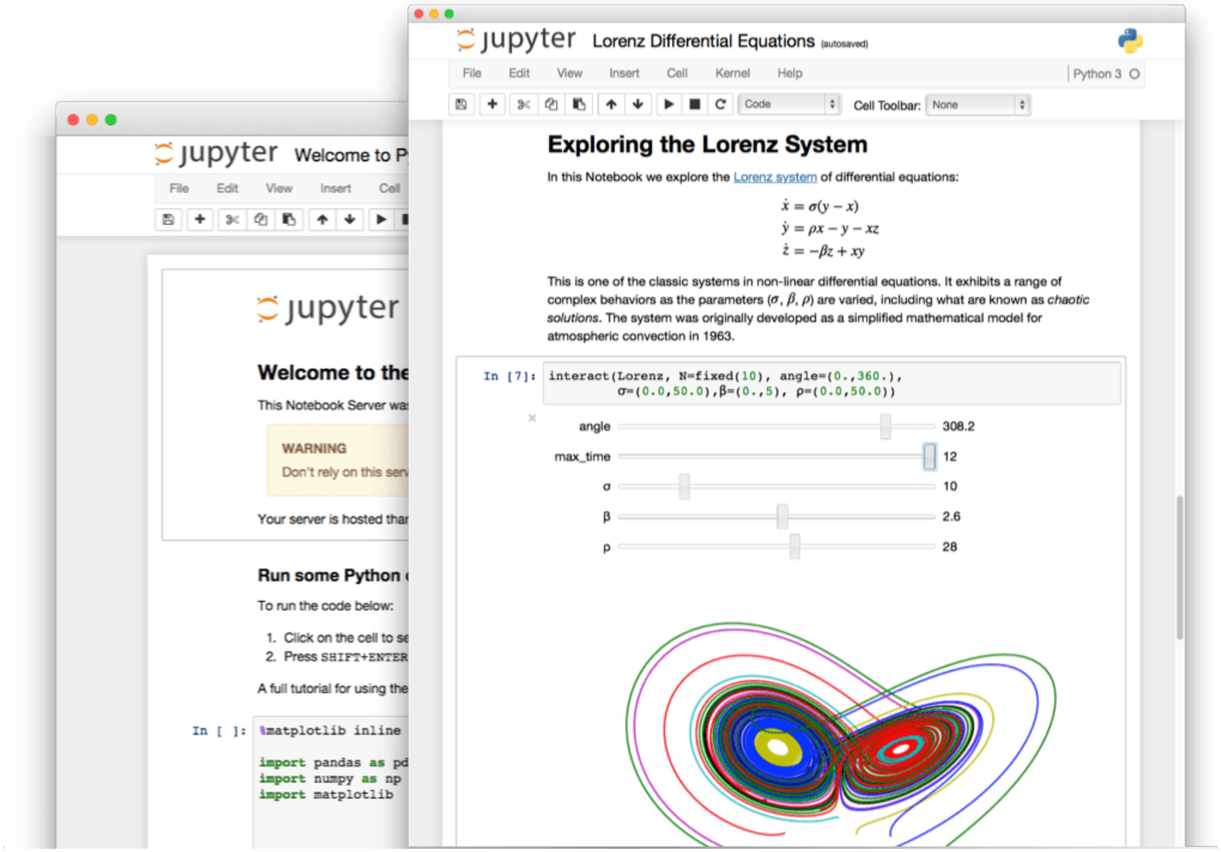



Open Notebooks are documents that contain equations, visualisations, narrative text and live code that can be executed independently and interactively, with output visible immediately beneath the input.

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/

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https://doi.org/10.6084/m9.figshare.10255727

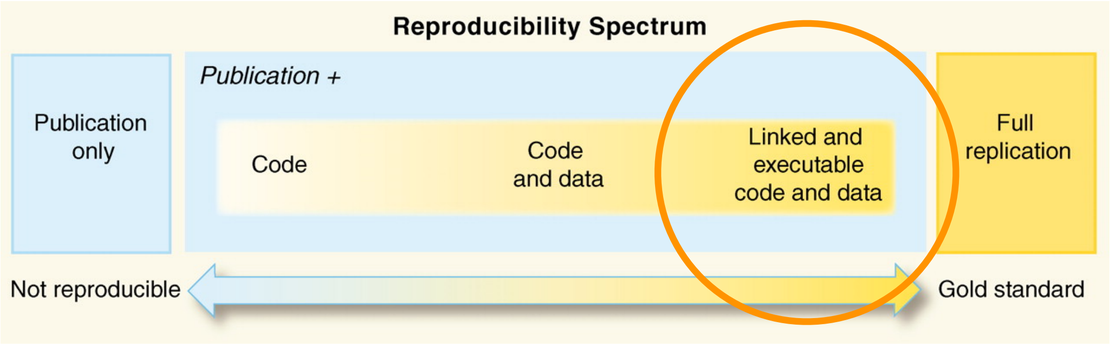
# Package data, code & analyses through Containerisation such as with Docker & Singularity

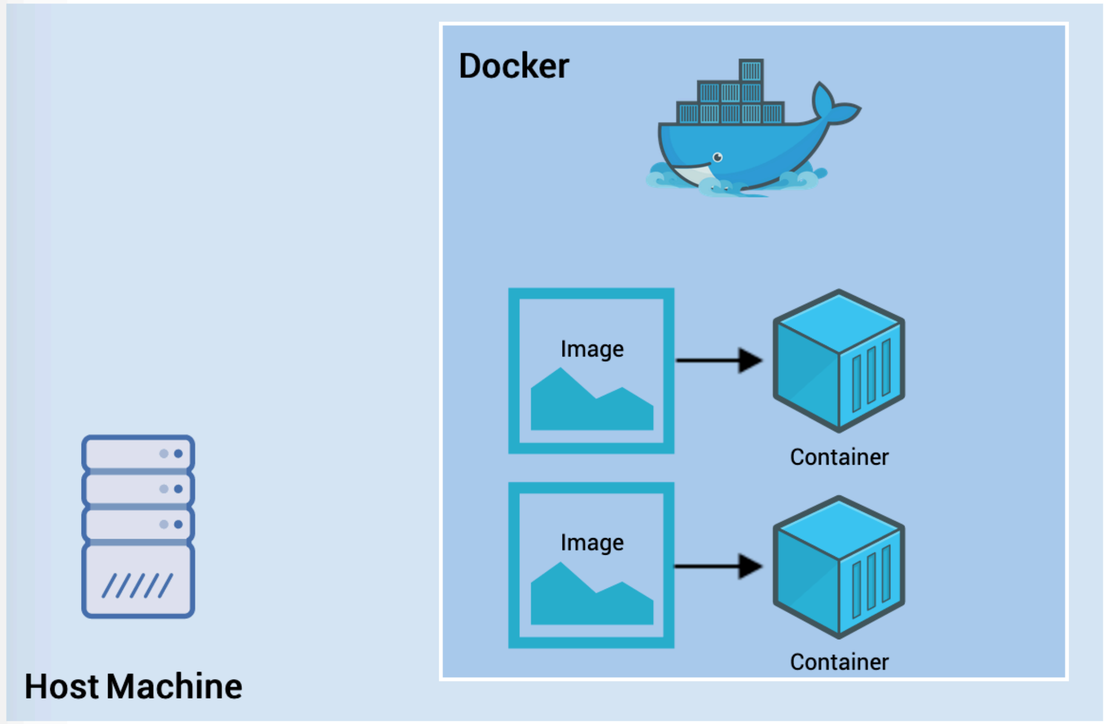
A container image is a lightweight, standalone, executable package of software that includes everything needed to run an application: code, runtime, system tools, system libraries and settings.

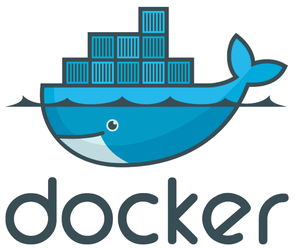
Containers can be used to package entire scientific workflows, software and libraries, and even data. This means that you don't have to ask your cluster admin to install anything for you - you can put it in a container and run.

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.**



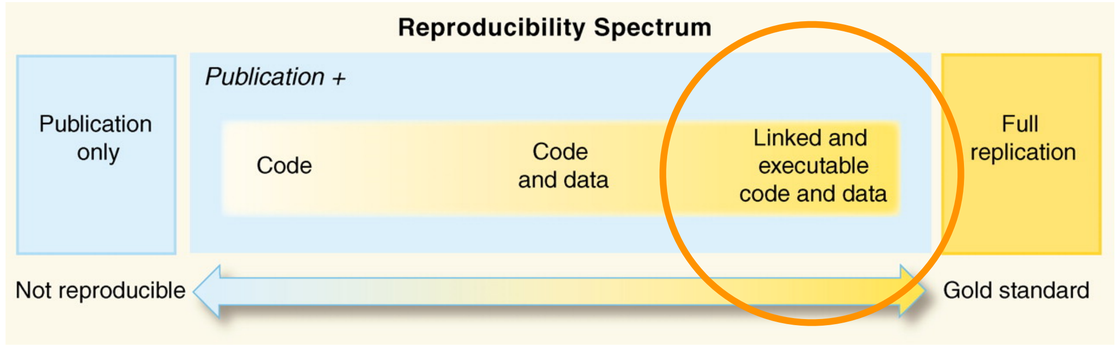




# Don’t want to build your own container? Use Binder!

- 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




binder

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 repository name or URL — GitHub

Git branch, tag, or commit — Path to a notebook file (optional)

Git branch, tag, or commit — Path to a notebook file (optional) — File — launch

Copy the URL below and share your Binder with others:

Fill in the fields to see a URL for sharing your Binder.

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

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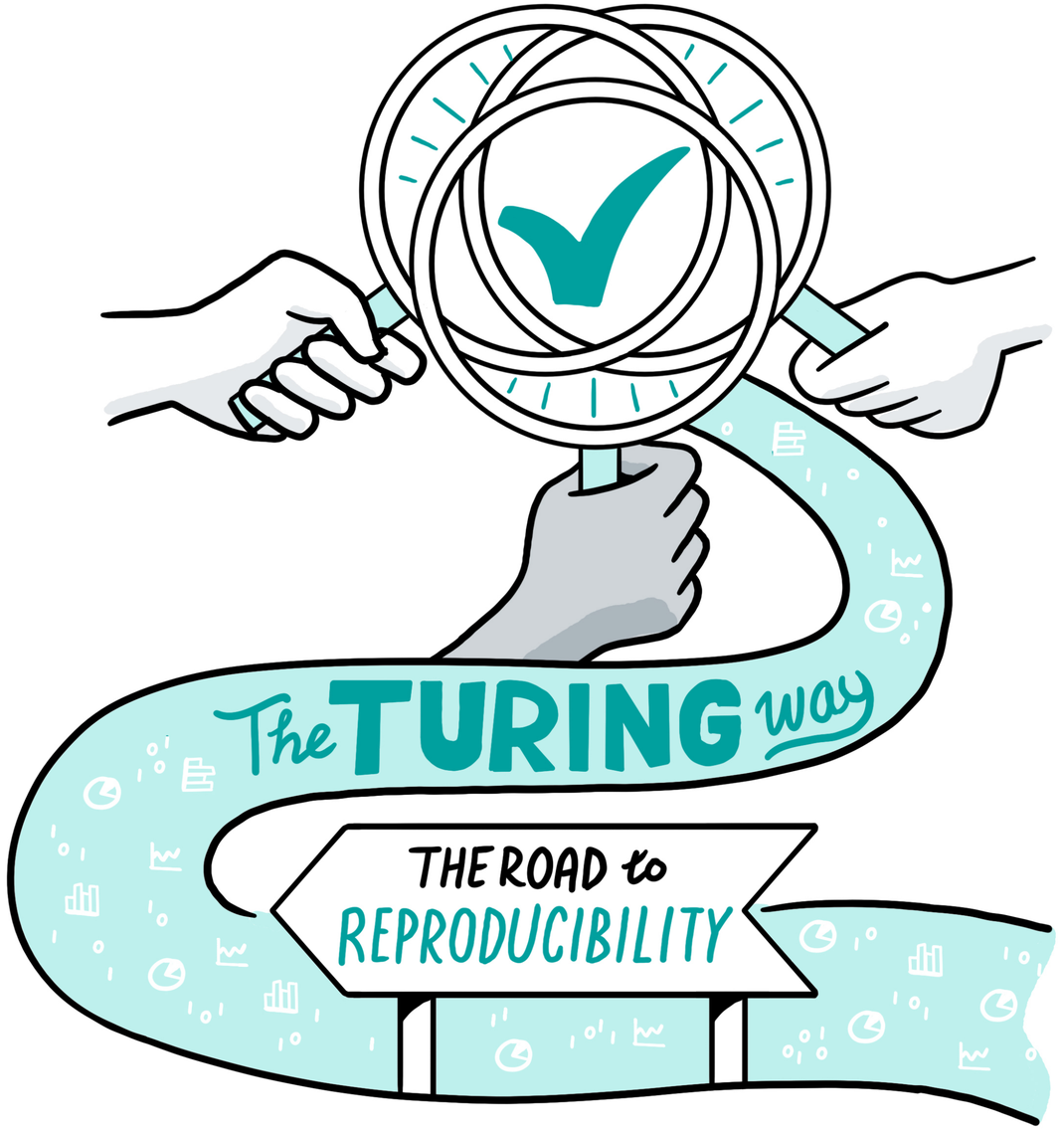
https://doi.org/10.6084/m9.figshare.10255727

# 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

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# 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**:

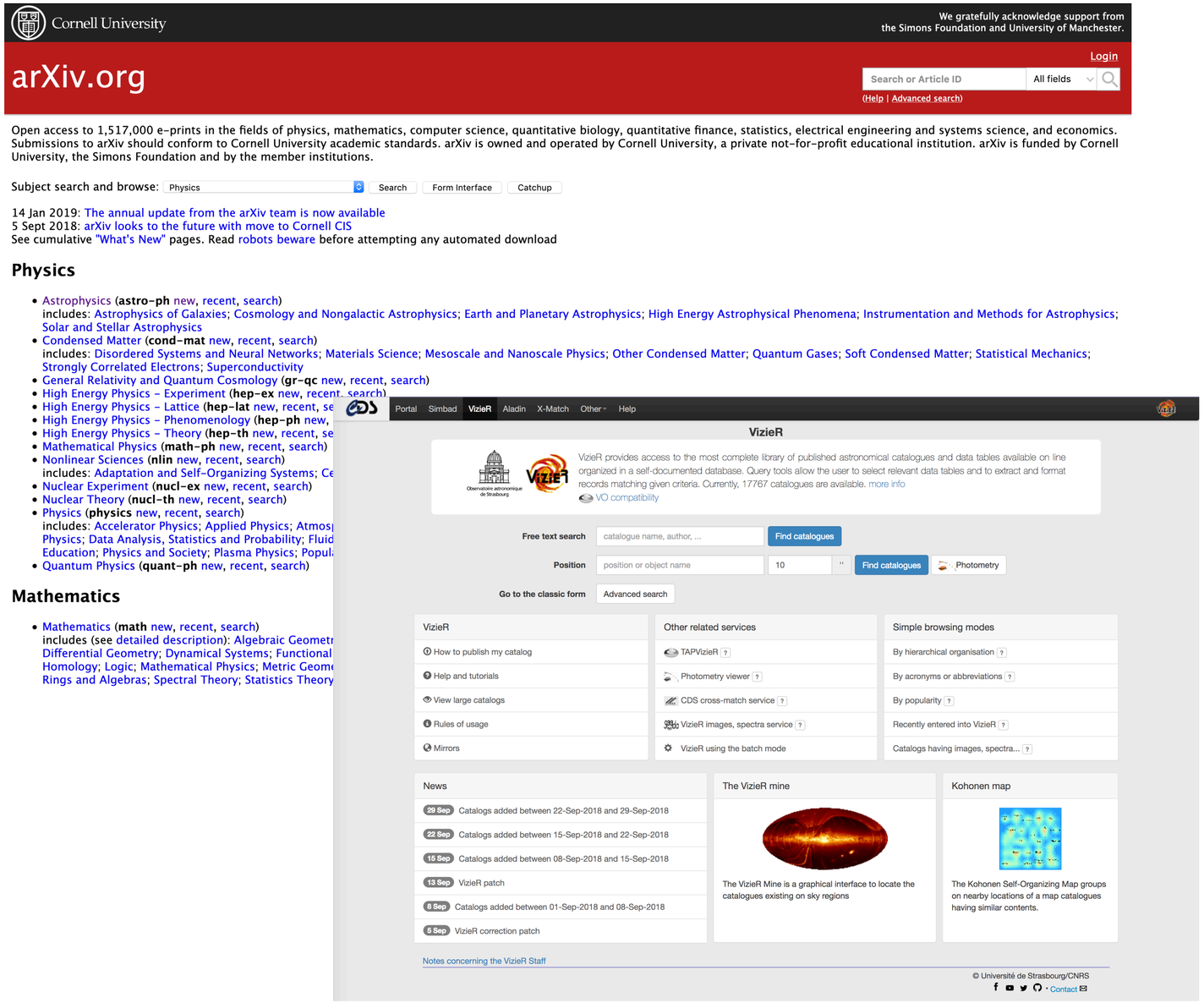
- Raw data via instrument archives
- Surveys through VizieR
- Meta-data through Simbad

**Open Source**:

- Projects and tools such as Astropy
- The CASA pipeline for e-MERLIN data

**Citizen Science**:

- Pulsar Hunters
- Galaxy Zoo




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

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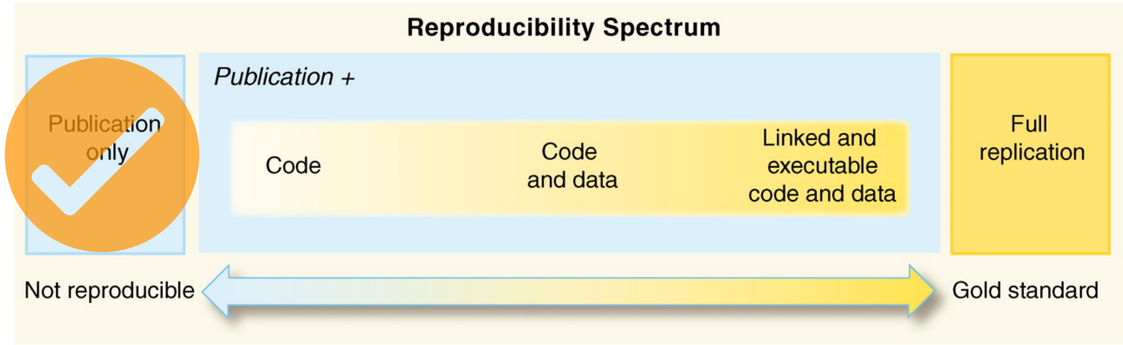
# Open Access to publication






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)

### Submission history

From: Charles Walker [view email]
**[v1]** Wed, 4 Apr 2018 18:03:06 UTC (897 KB)



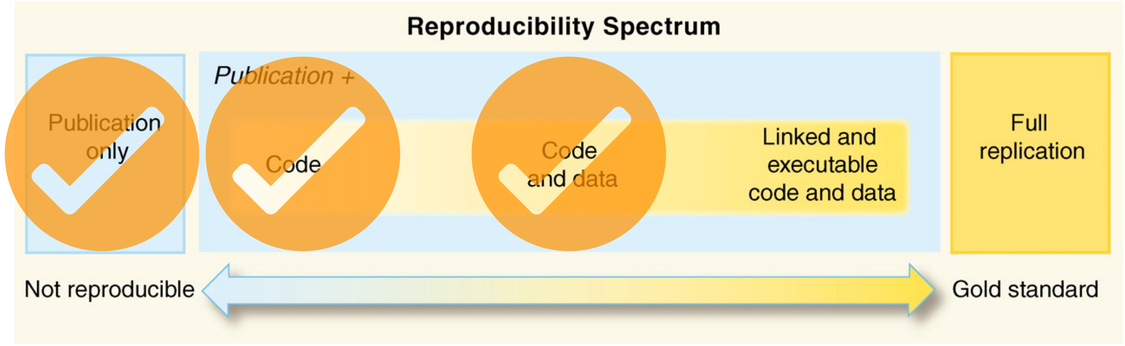
### 4.4. Concluding remarks

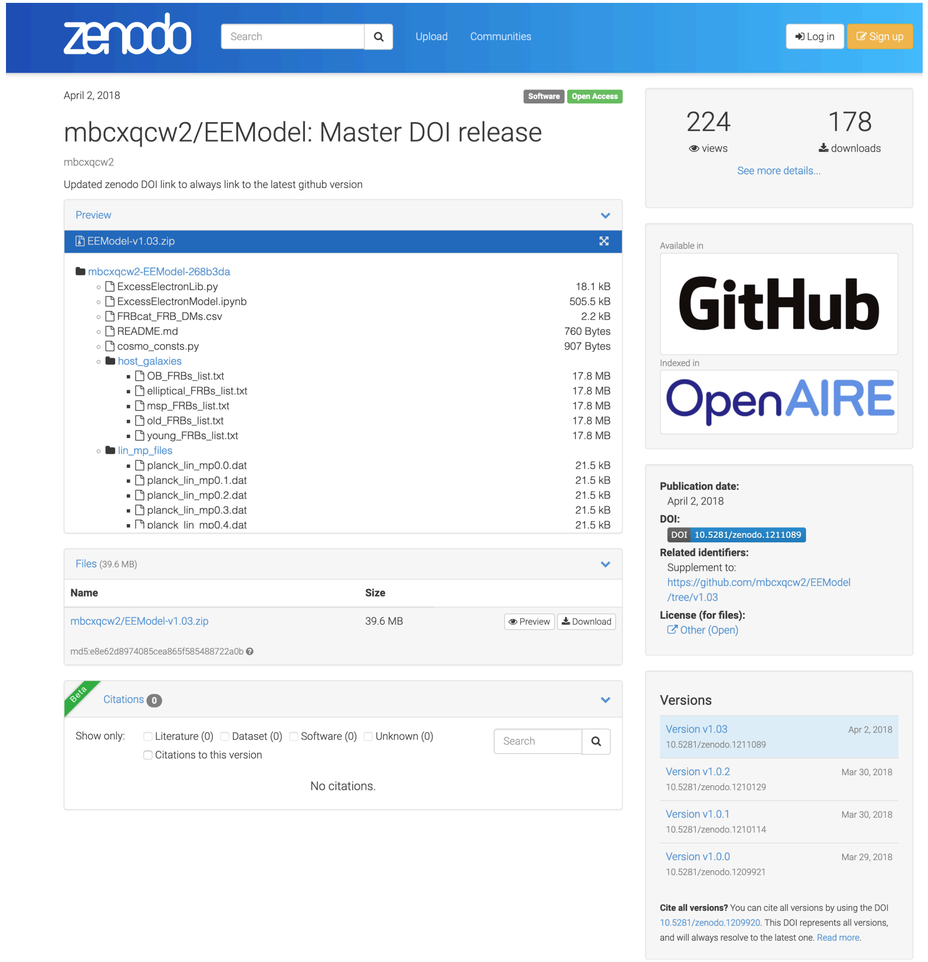
We present a framework for exploration of the statistical relationship between FRB redshifts and dispersion measures, which provides the basis for:

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 ($> 400$ pc cm$^{-3}$) in the rest frame, and as expected, that $\mathrm{DM_{host}}$ 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 $P(\mathrm{DM}|z_s)$ profiles out to $z_s = 3$.
2. More rigorous uncertainties to be placed on FRB redshifts than are currently standard practice. By consulting $P(z_s|\mathrm{DM})$ 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 $\mathrm{DM_{obs}}$ 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 $\mathrm{DM_{IGM}}$ and $\mathrm{DM_{host}}$ using their respective redshift dependences.

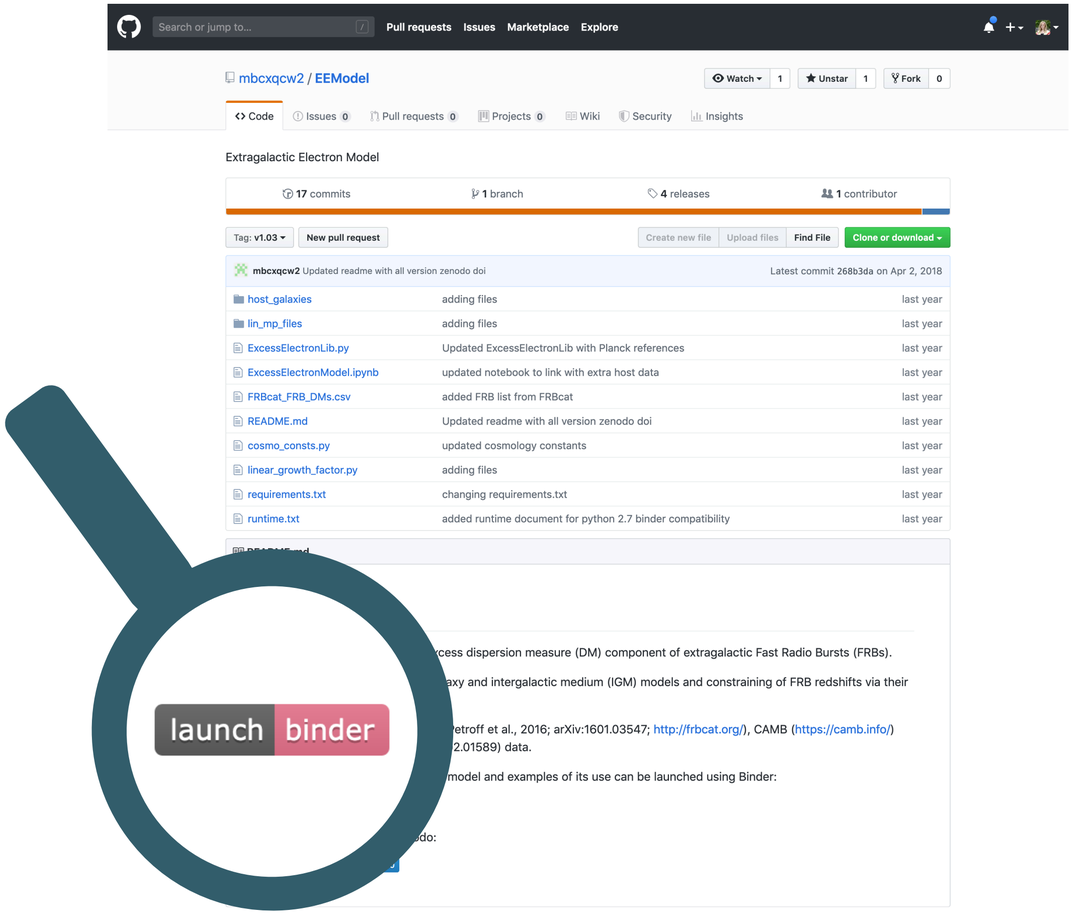
Walker, Ma & Breton, https://arxiv.org/abs/1804.01548

# Open Access to code & data



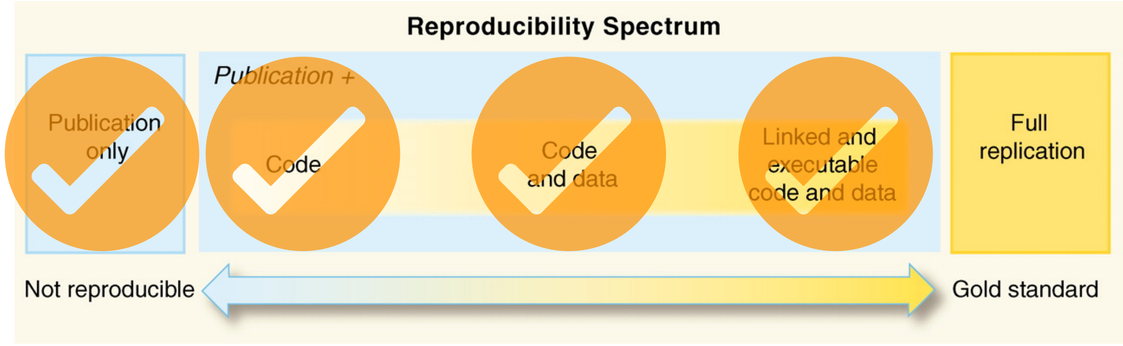



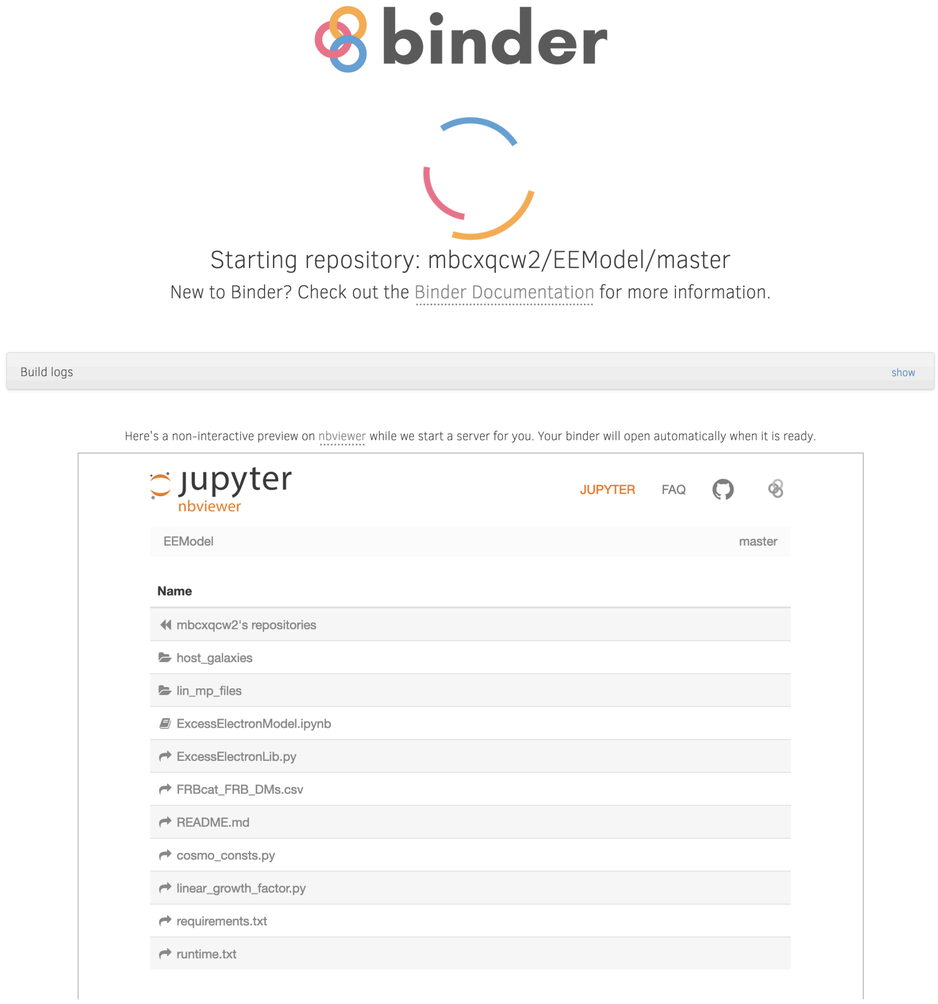

https://zenodo.org/record/1211089

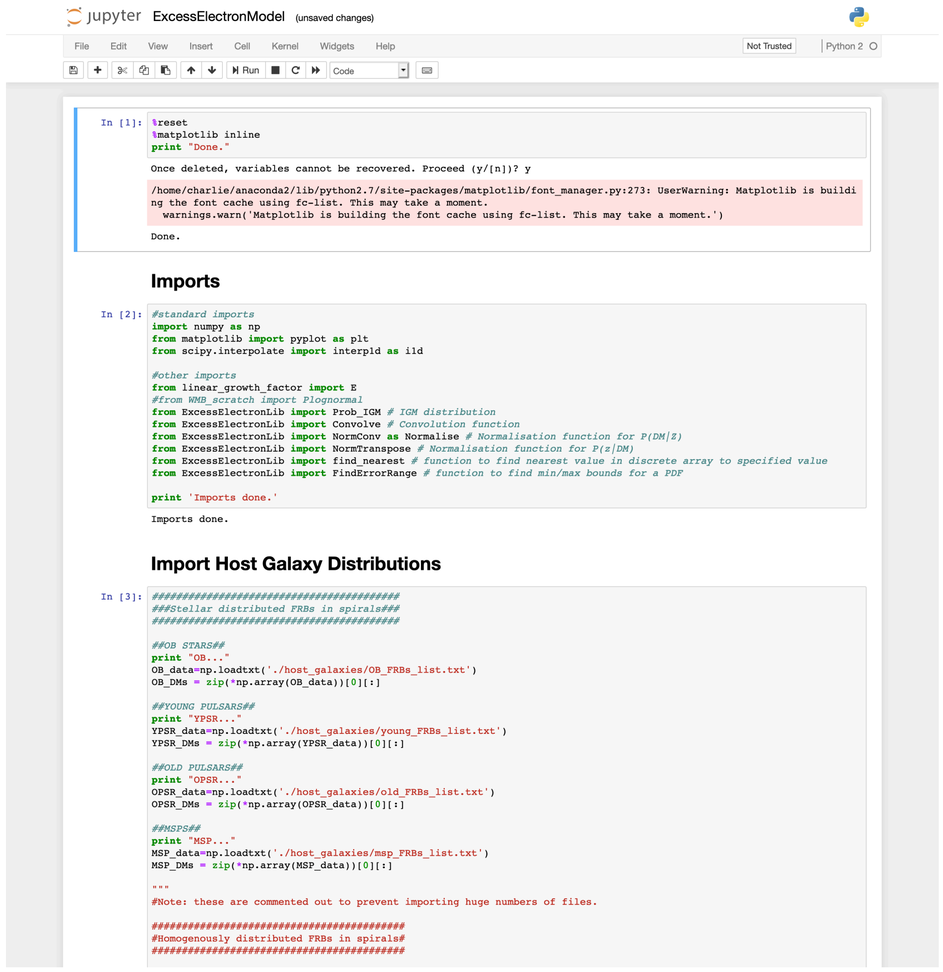



https://github.com/mbcxqcw2/EEModel/tree/v1.03

# Linked & executable code & data

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https://doi.org/10.6084/m9.figshare.10255727

# 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

Papers that cite

**Constraining Redshifts of Unlocalised Fast Radio Bursts**

view this list in a search results page

1 2019MNRAS.488.4220H 2019/09
**Fast radio burst dispersion measures and rotation measures and the origin of intergalactic magnetic fields**
Hackstein, S.; Brüggen, M.; Vazza, F. *and 2 more*

2 2019arXiv190902821W 2019/09
**Probing Diffuse Gas with Fast Radio Bursts**
Walters, Anthony; Ma, Yin-Zhe; Sievers, Jonathan *and 1 more*

3 2019arXiv190706440R 2019/07
**A Roadmap for Astrophysics and Cosmology with High-Redshift 21 cm Intensity Mapping**
Reionization Array, The Hydrogen Epoch of; Collaboration; Aguirre, James E. *and 29 more*

4 2019NatAs...3..928R 2019/07
**The prevalence of repeating fast radio bursts**
Ravi, Vikram

5 2019MNRAS.486...70B 2019/06
**A southern sky search for repeating fast radio bursts using the Australian SKA Pathfinder**
Bhandari, S.; Bannister, K. W.; James, C. W. *and 4 more*

6 2019BAAS...51c.420R 2019/05
**Fast Radio Burst Tomography of the Unseen Universe**
Ravi, Vikram; Battaglia, Nicholas; Burke-Spolaor, Sarah *and 13 more*

7 2019ApJ...872...88R 2019/02
**Measuring the Circumgalactic and Intergalactic Baryon Contents with Fast Radio Bursts**
Ravi, Vikram

8 2018MNRAS.480.3907V 2018/11
**Probing the origin of extragalactic magnetic fields with Fast Radio Bursts**
Vazza, F.; Brüggen, M.; Hinz, P. M. *and 3 more*

9 2018ApJ...867L..10M 2018/11
**A Search for the Host Galaxy of FRB 171020**
Mahony, Elizabeth K.; Ekers, Ron D.; Macquart, Jean-Pierre *and 11 more*

10 2018PhRvD..98j3518M 2018/11
**Finding the missing baryons with fast radio bursts and Sunyaev-Zeldovich maps**
Muñoz, Julian B.; Loeb, Abraham

# Takeaways

- “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-IqA

- Get in touch! Email: rachael.ainsworth@manchester.ac.uk