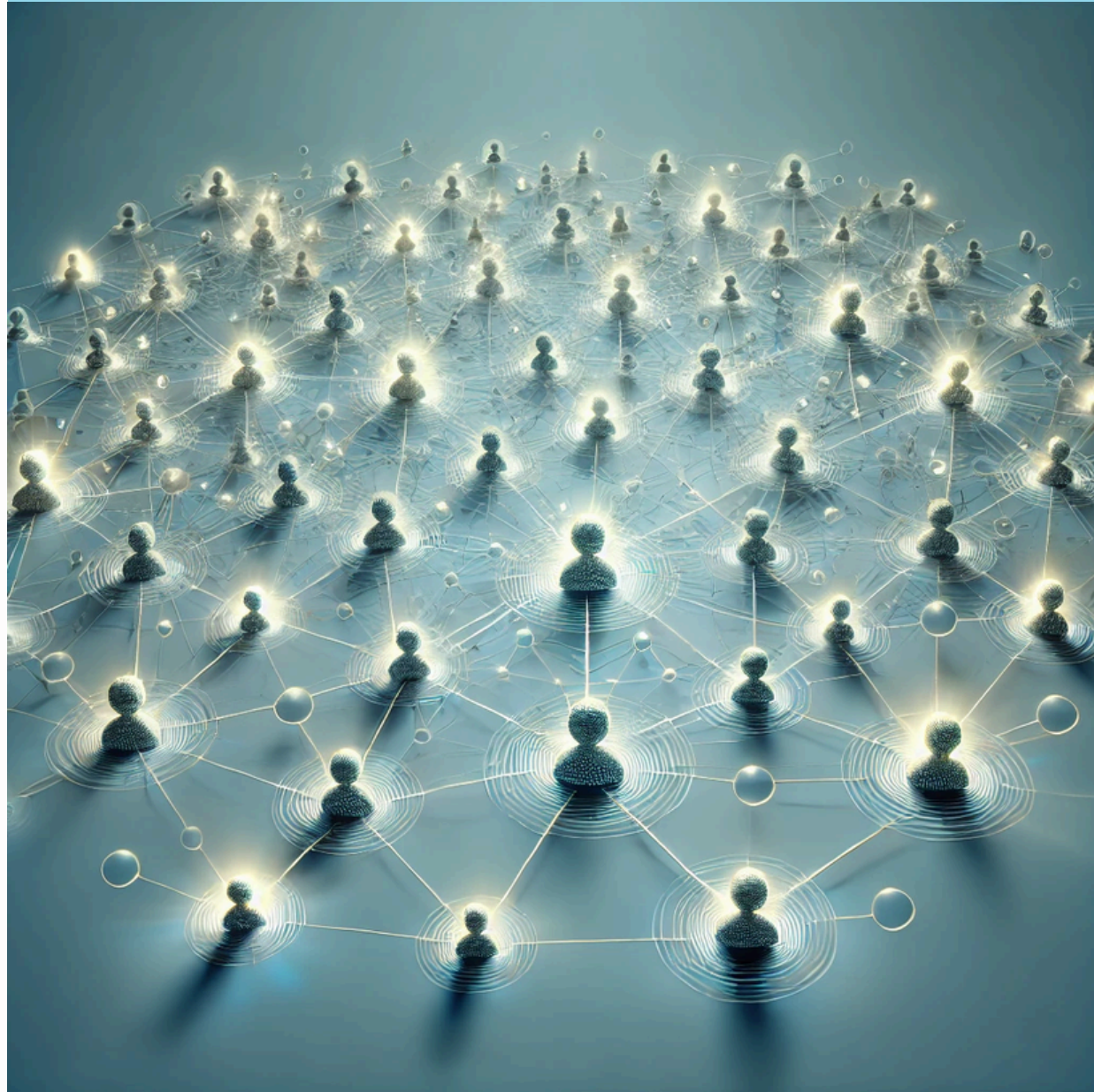


I Need **One More** Evaluation :))

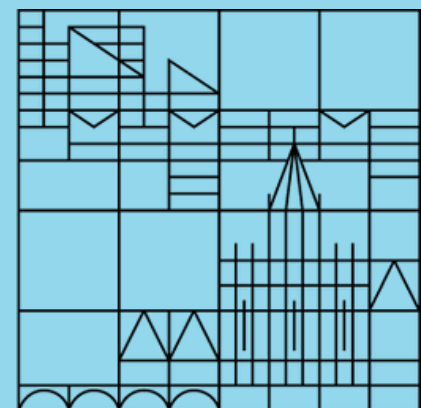
Your feedback is super important for me!

- If you have suggestions for topics to include or topics you found too boring or not very relevant, please share them
- Also if you have suggestions on how to improve the coding sessions I'll be happy to read them





Universität
Konstanz



UNIVERSITÄT KONSTANZ

Online Social Networks

Network Science of
Socio-Economic Systems
Giordano De Marzo

Recap

Firms Output Networks

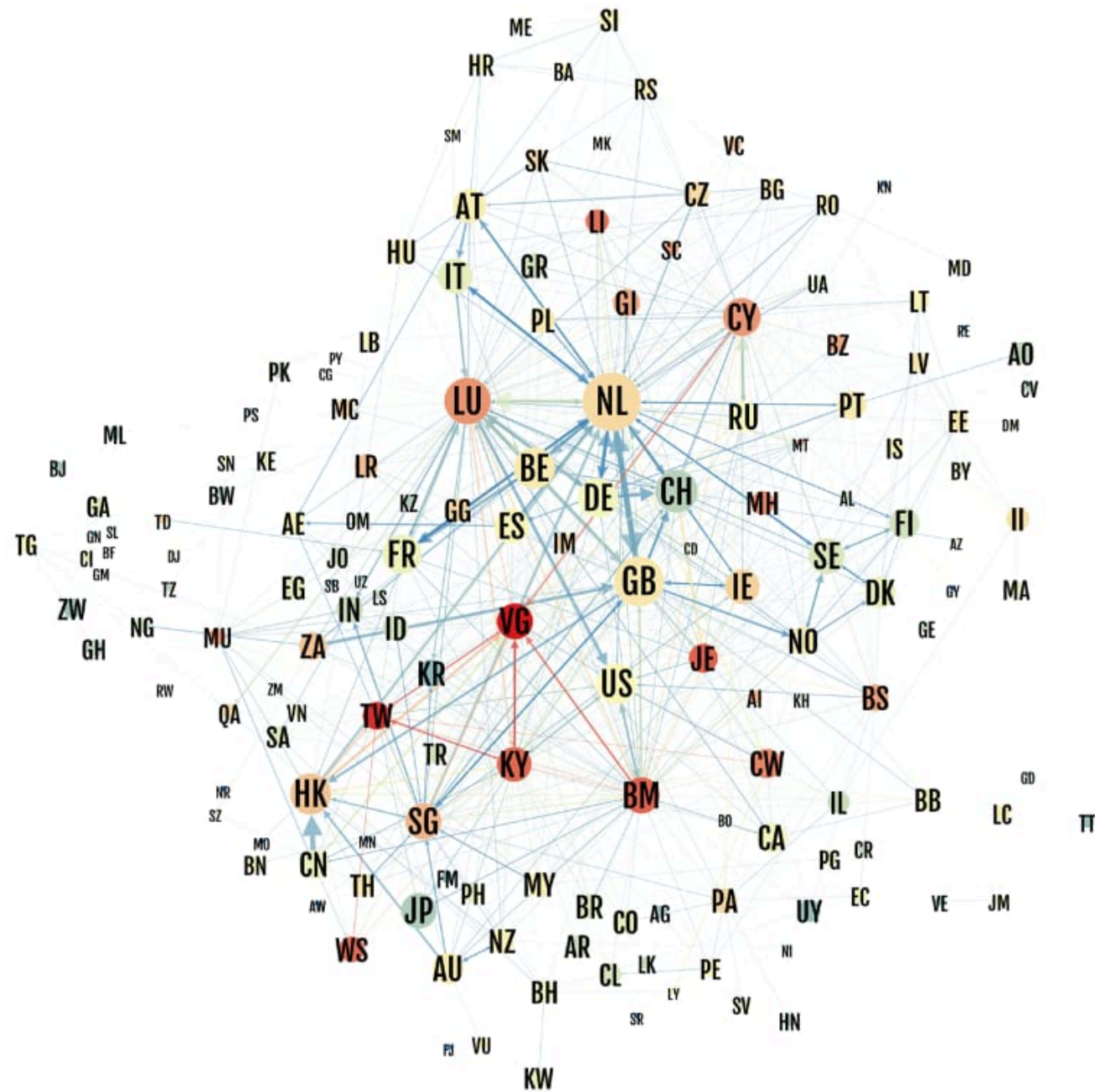
Firms can be studied looking at their outputs, such as products or activities. A nested or block-nested structure is observed.

Ownership and Directors Networks

Ownership Networks links firm in a directed graph following ownership relations. These links are often used to avoid taxation.

Supply Chains

Supply chain links all firms in an economy following exchange of products or services. These networks allow to predict the effect of shocks and to guide policies.



Outline

1. Polarization and Online Echo Chambers
2. Spreading of (Mis)Information
3. Online Debunking
4. Info About Exam



A network diagram with nodes and connecting lines, overlaid on a blue background. The nodes are represented by small circles, some of which are black and others are light grey. The lines connecting them are thin and light grey. The overall structure is a complex, interconnected web of nodes and edges, suggesting a network or community structure.

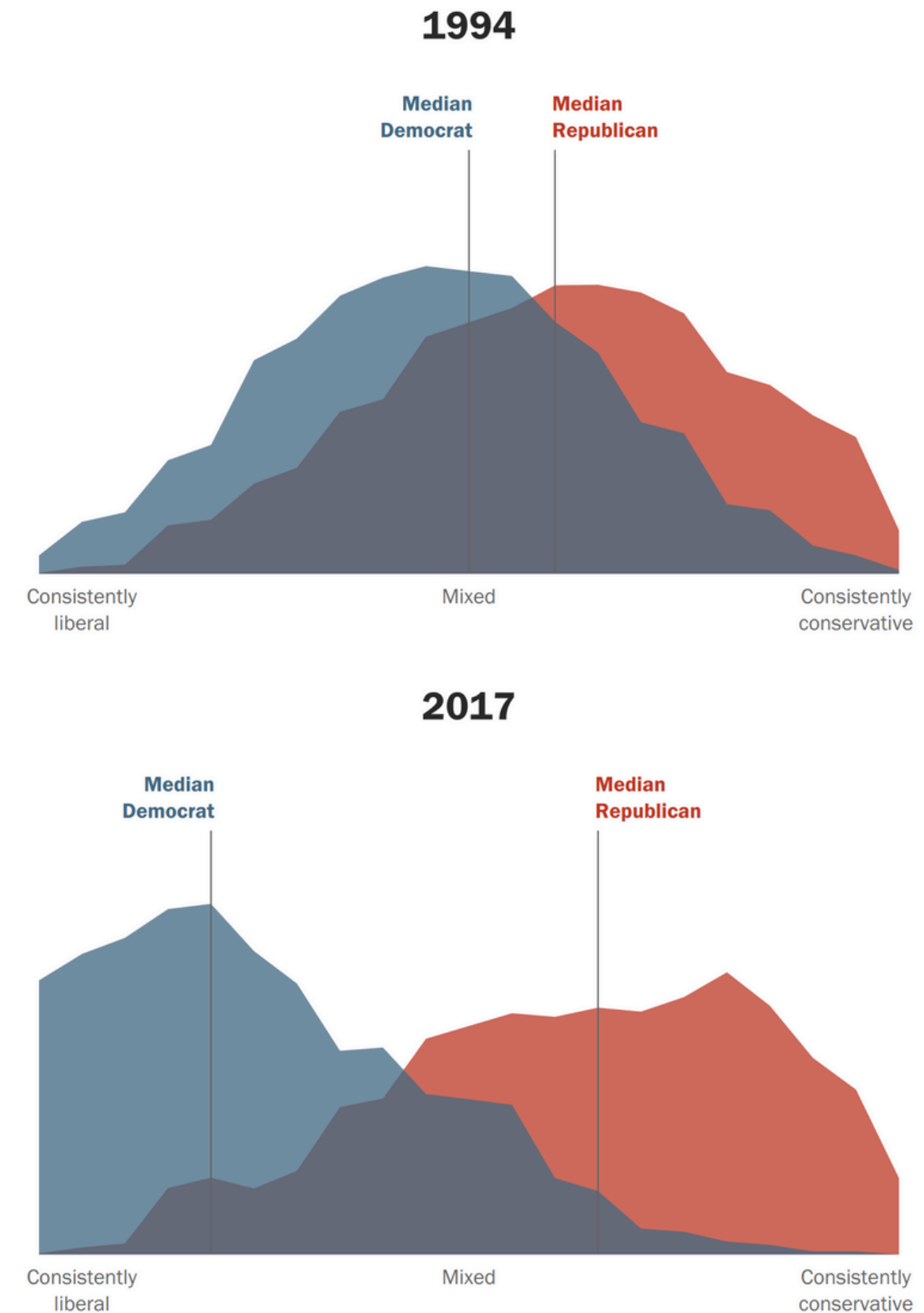
Polarization and Online Eco Chambers

The Rise of Polarization

Polarization, particularly ideological polarization

- is a division of individuals' beliefs along opposing ends of a political or ideological spectrum
- It captures how groups increasingly cluster around distinct ideological positions

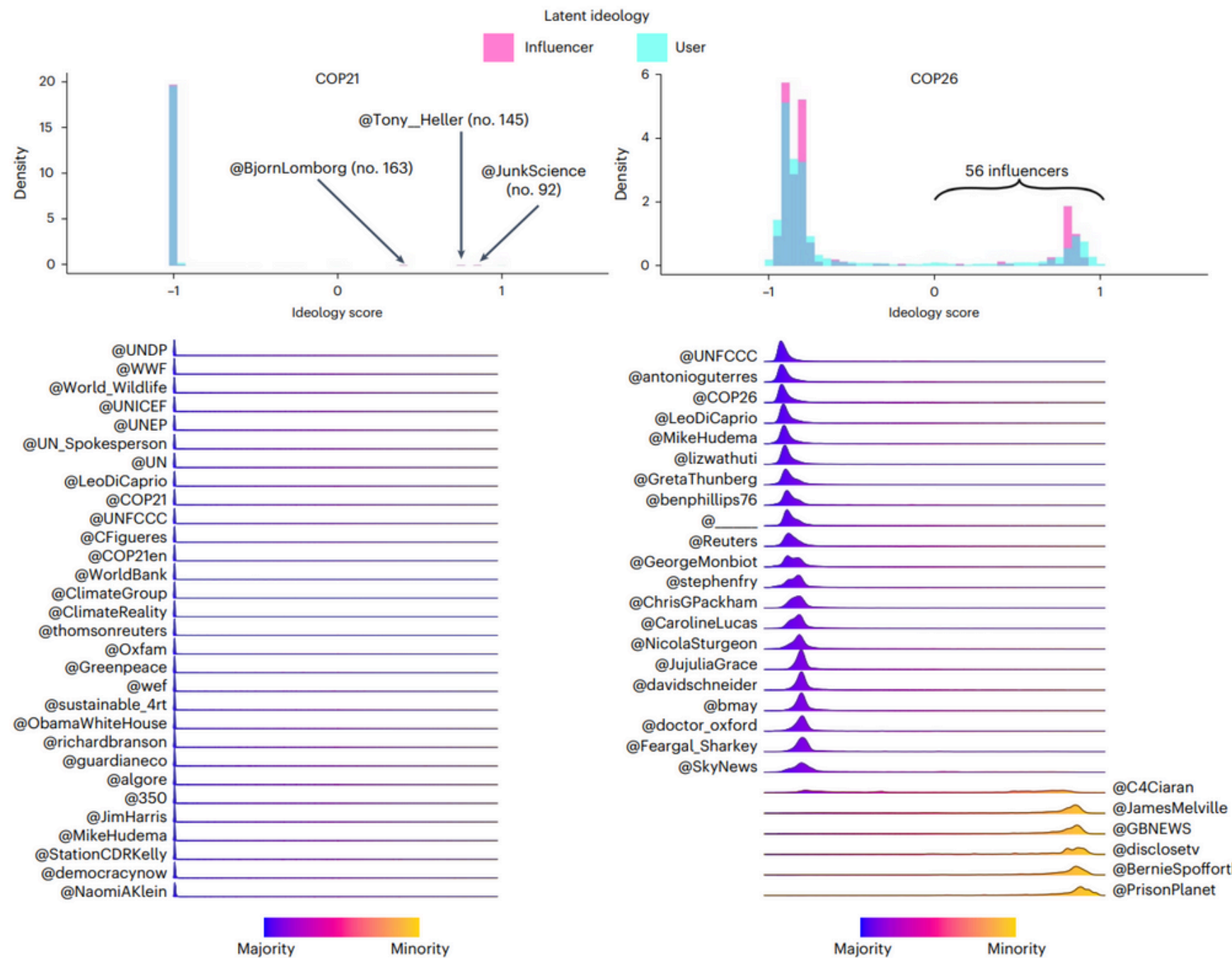
The figure illustrates the shift in ideological distribution of Democrats and Republicans in the U.S. between 1994 and 2017



Online Polarization

Polarization has increasingly shifted to online platforms

- social media plays a crucial role in shaping ideological divides.
- individuals engage primarily with like-minded content
- this can lead to the formation of echo chambers and filter bubbles that amplify pre-existing beliefs



The figure illustrates the rise of online polarization in discussions surrounding climate change during COP21 and COP26.

Falkenberg, Max, et al. "Growing polarization around climate change on social media." *Nature Climate Change* 12.12 (2022): 1114-1121.

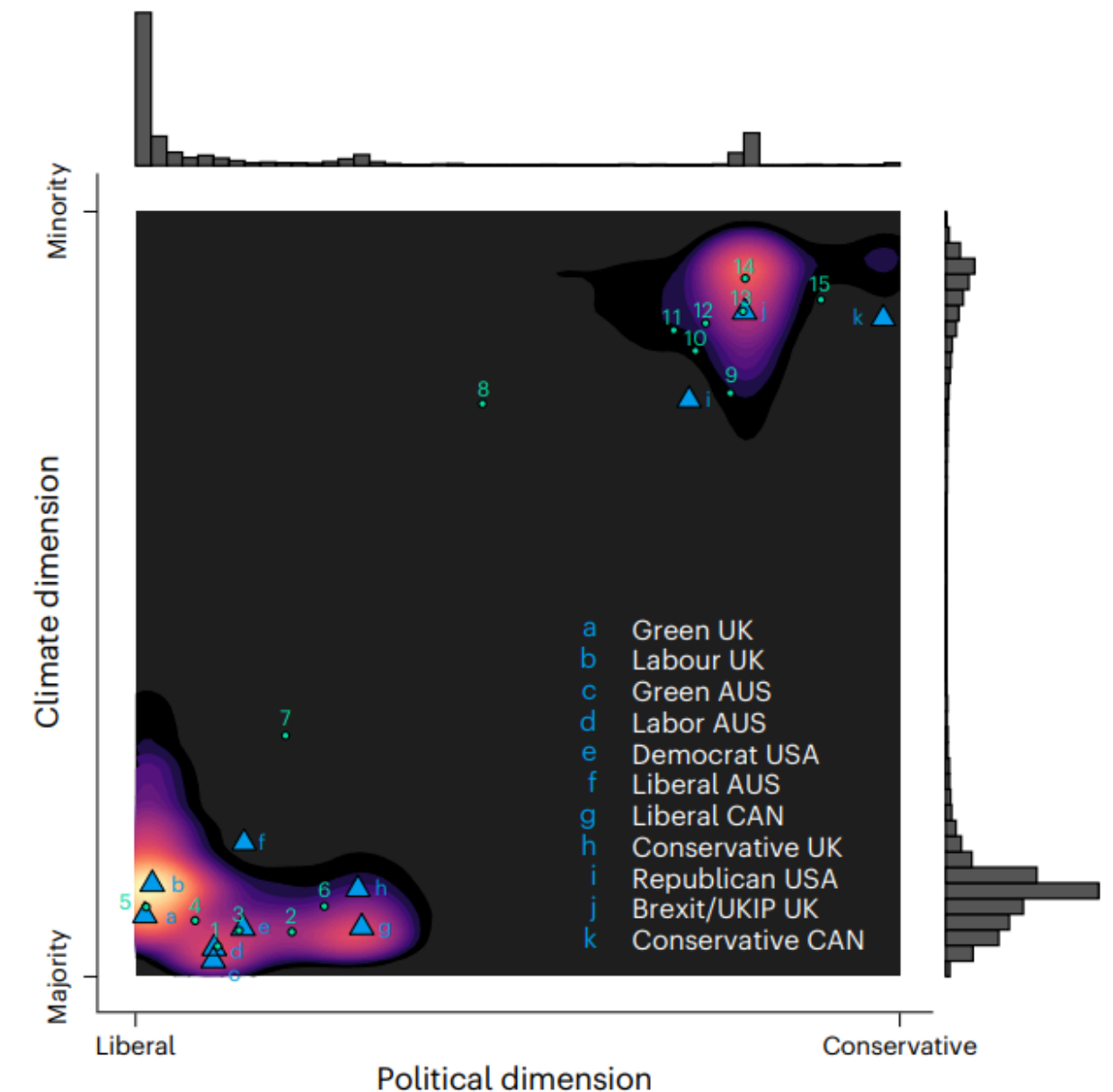
More than One Dimension

Polarization is a multidimensional phenomenon

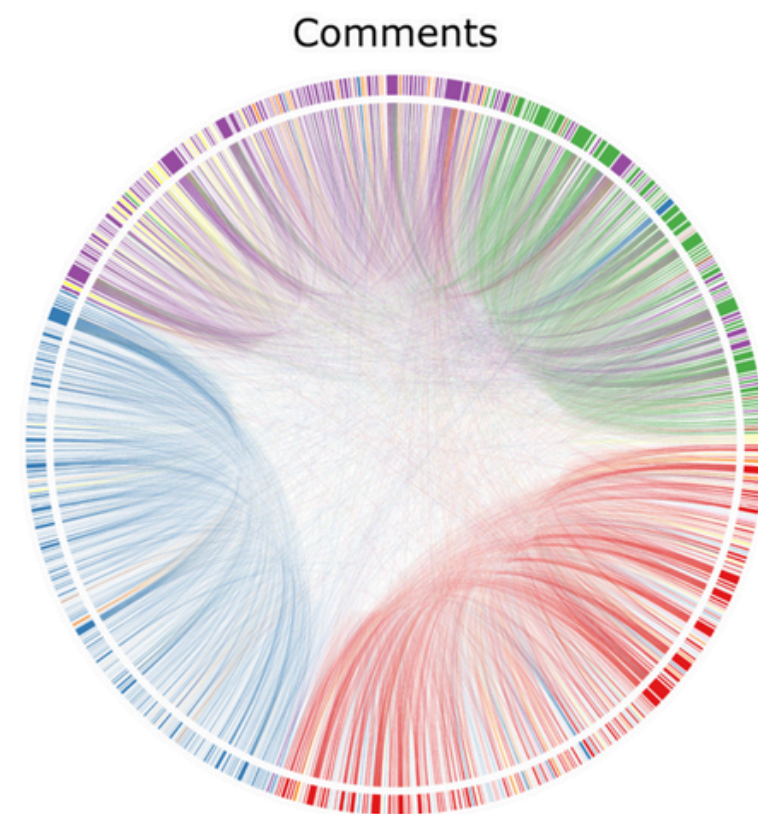
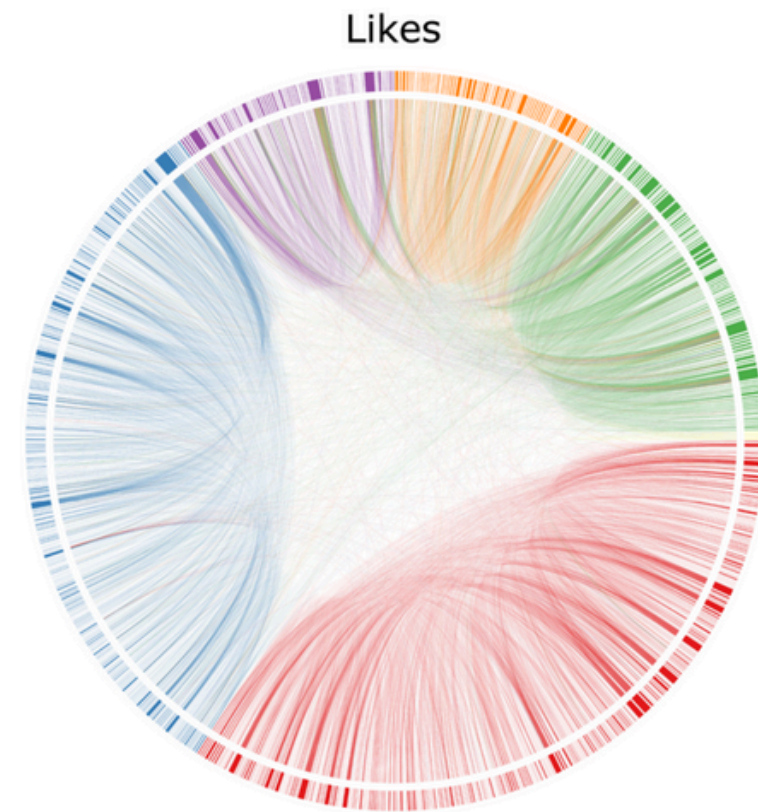
- Individuals and groups often polarize along different
- dimensions can be correlated
 - exemplified: political ideology and attitudes toward climate change.

These dimensions can reinforce each other, leading to deeper societal divisions.

- 1 Anti-Morrison
- 2 Biodiversity & Localism, Women at COP, Climate Finance, Youth, Climate Justice
- 3 Decolonise Climate
- 4 Sustainable Transport
- 5 Activists for Climate Action
- 6 Climate Crisis
- 7 Anti-Johnson
- 8 Anti-Sturgeon
- 9 Climate Alarmists
- 10 Wind Energy & Nuclear
- 11 Thunberg Cult
- 12 Chinese Absence, Vaccine Passports
- 13 Anti-Biden, Didn't Vote Green, Arctic Ice, Climate "Scam", Benefits of Warming
- 14 Illegal Immigration, Net Zero Referendum, Private Jets, Hypocrisy, CO₂
- 15 Anti-Trudeau



The Network of News Outlets



In this study, researchers investigate how echo chambers emerge in online news consumption

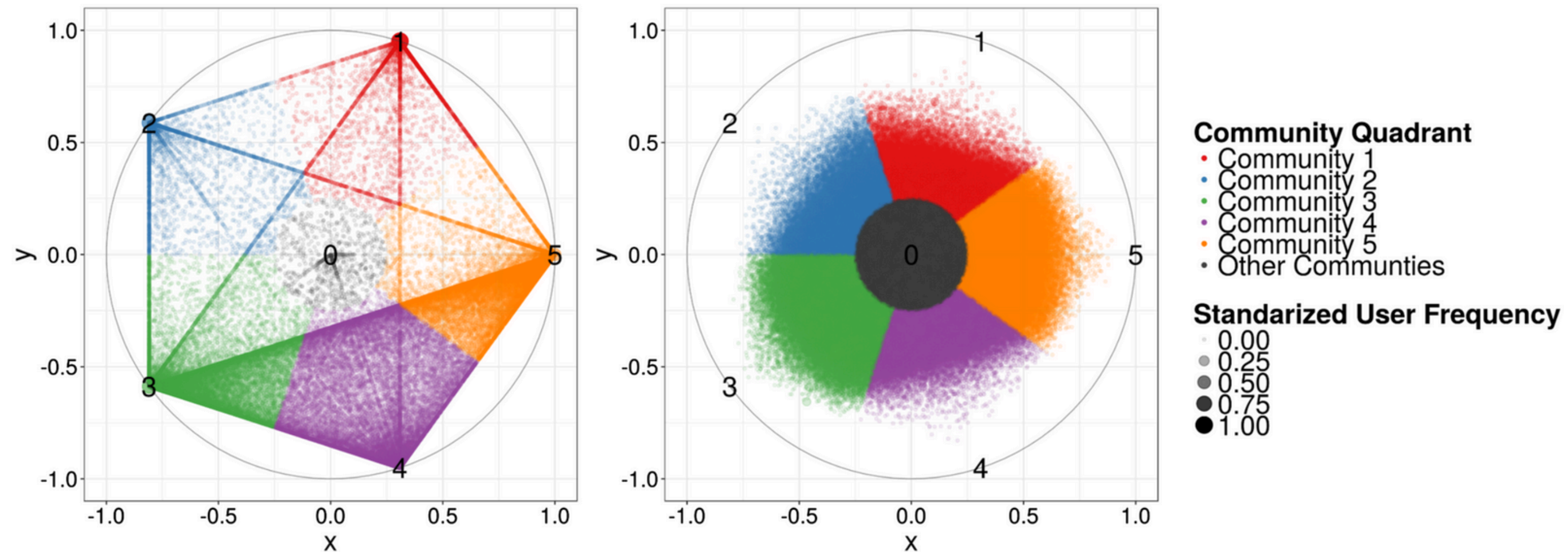
- activity of 376 million users engaging with anglophone news outlets
- 6-year period (2010–2015)
- they build two bipartite network of users and news outlets, based on comments and likes

These networks can be projected to reconstruct the network of news outlets pages

- users tend to focus on a limited set of pages
- community detection algorithms reveal a clustered structure

Users' Polarization

Users on Facebook tend to confine their interactions within specific news clusters, reinforcing echo chambers. User activity is highly polarized, with most attention focused on a single community of pages.



Schmidt, Ana Lucía, et al. "Anatomy of news consumption on Facebook." *Proceedings of the National Academy of Sciences* 114.12 (2017): 3035-3039.


Reconstructing Users' Leaning

In order to study echo chambers we need to reconstruct users' leaning x . A possibility is to use the shared or commented content as a measure

$$x_i \equiv \frac{\sum_{j=1}^{a_i} c_j}{a_i}.$$

New York Times

Has this Media Source failed a fact check? LET US KNOW HERE.

Share:  434

FACTUAL REPORTING						
Very Low	Low	Mixed	Mostly Factual	High	Very High	
Extreme	Left	Left-Center	Least Biased	Right-Center	Right	Extreme

LEFT-CENTER BIAS

These media sources have a slight to moderate liberal bias. They often publish factual information that utilizes loaded words (wording that attempts to influence an audience by using appeal to emotion or stereotypes) to favor liberal causes. These sources are generally trustworthy for information, but may require further investigation. [See all Left-Center sources.](#)


- Overall, we rate the New York Times Left-Center biased based on word and story selection that moderately favors the left, but highly factual and considered one of the most reliable sources for news information due to proper sourcing and well respected journalists/editors. The failed fact checks that occurred were on Op-Ed's and not straight news reporting.

Detailed Report

Factual Reporting: **HIGH**
Country: **USA**
World Press Freedom Rank: **USA 48/180**

Breitbart

Has this Media Source failed a fact check? LET US KNOW HERE.

Share:  1,500

FACTUAL REPORTING						
Very Low	Low	Mixed	Mostly Factual	High	Very High	
Extreme	Left	Left-Center	Least Biased	Right-Center	Right	Extreme

QUESTIONABLE SOURCE

A questionable source exhibits one or more of the following: extreme bias, consistent promotion of propaganda/conspiracies, poor or no sourcing to credible information, a complete lack of transparency and/or is fake news. Fake News is the deliberate attempt to publish hoaxes and/or disinformation for the purpose of profit or influence ([Learn More](#)). Sources listed in the Questionable Category may be very untrustworthy and should be fact checked on a per article basis. Please note sources on this list are not considered fake news unless specifically written in the reasoning section for that source. [See all Questionable sources.](#)

- Overall, we rate Breitbart Questionable based on extreme right wing bias, publication of conspiracy theories and propaganda as well as numerous false claims.

Detailed Report

Reasoning: **Extreme Right, Propaganda, Conspiracy, Failed Fact Checks**
Country: **USA**
World Press Freedom Rank: **USA 48/180**

A Cross Platform Study

Being placed further right in the capabilities ladder, i.e. having more sophisticated activities, results in higher growth and survival

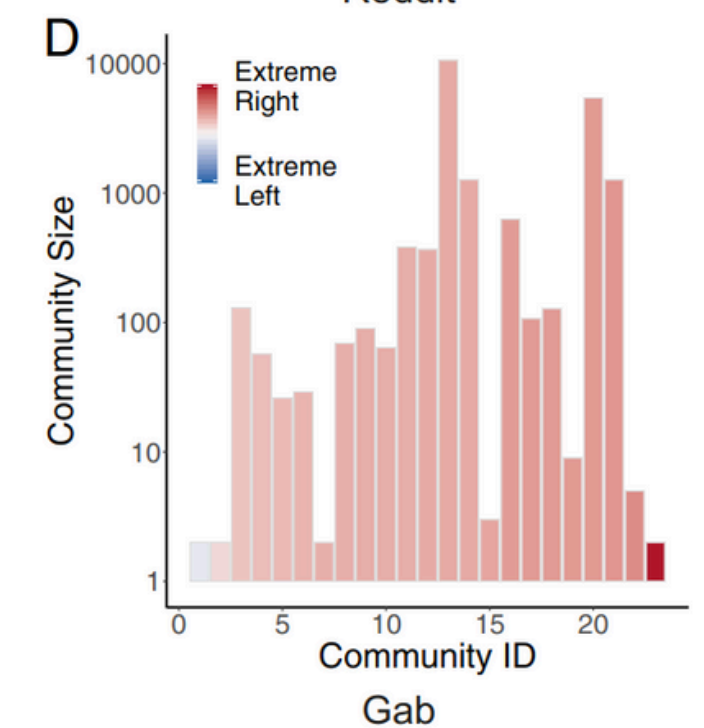
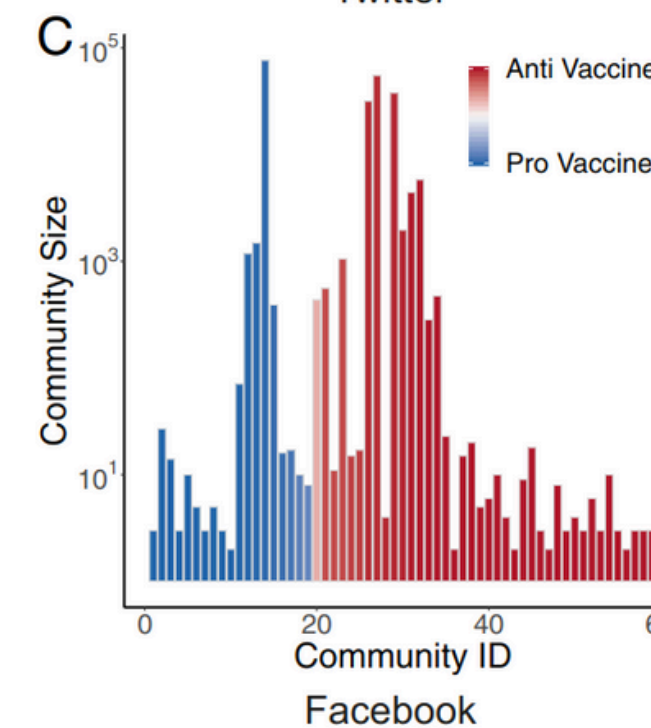
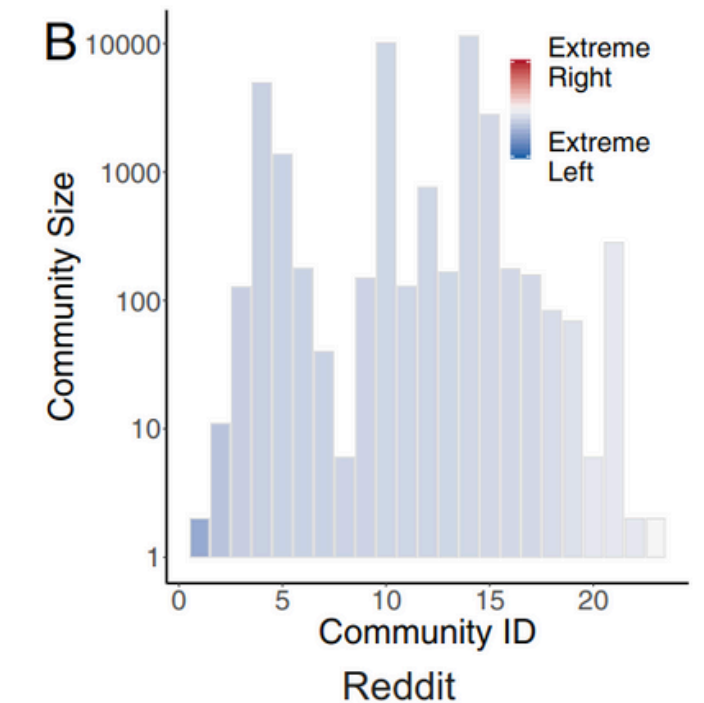
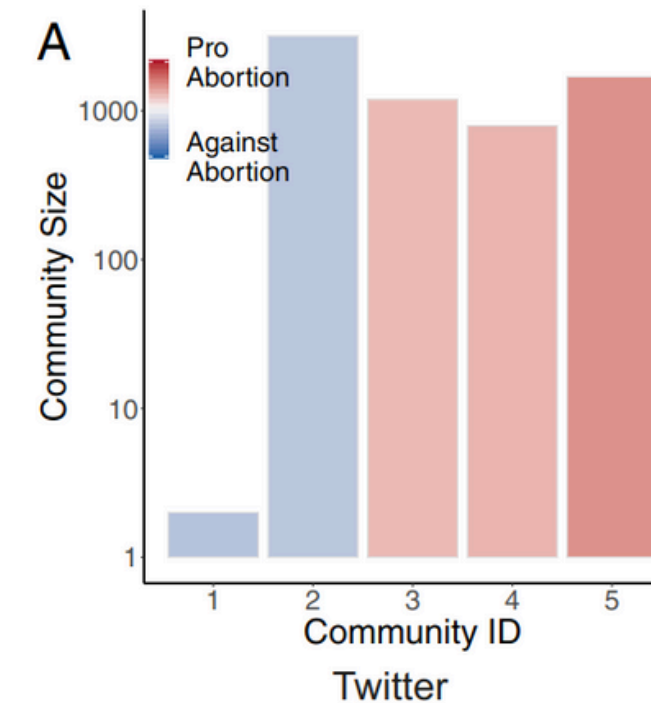
	Facebook	Twitter	Gab	Reddit
Network	co-comment network	following network	co-comment network	directed reply network
Leaning	likes to posts by pages (Anti-Vax [+1]/Pro-Vax [-1])	links in tweets by users (news outlet scores)	links in content by users (news outlet scores)	links in content by users (news outlet scores)

Cinelli, Matteo, et al. "The echo chamber effect on social media." Proceedings of the National Academy of Sciences 118.9 (2021): e2023301118.

Users' Communities

The analysis of community structures reveals the presence of homophilic interactions, where users with similar ideological leanings cluster together

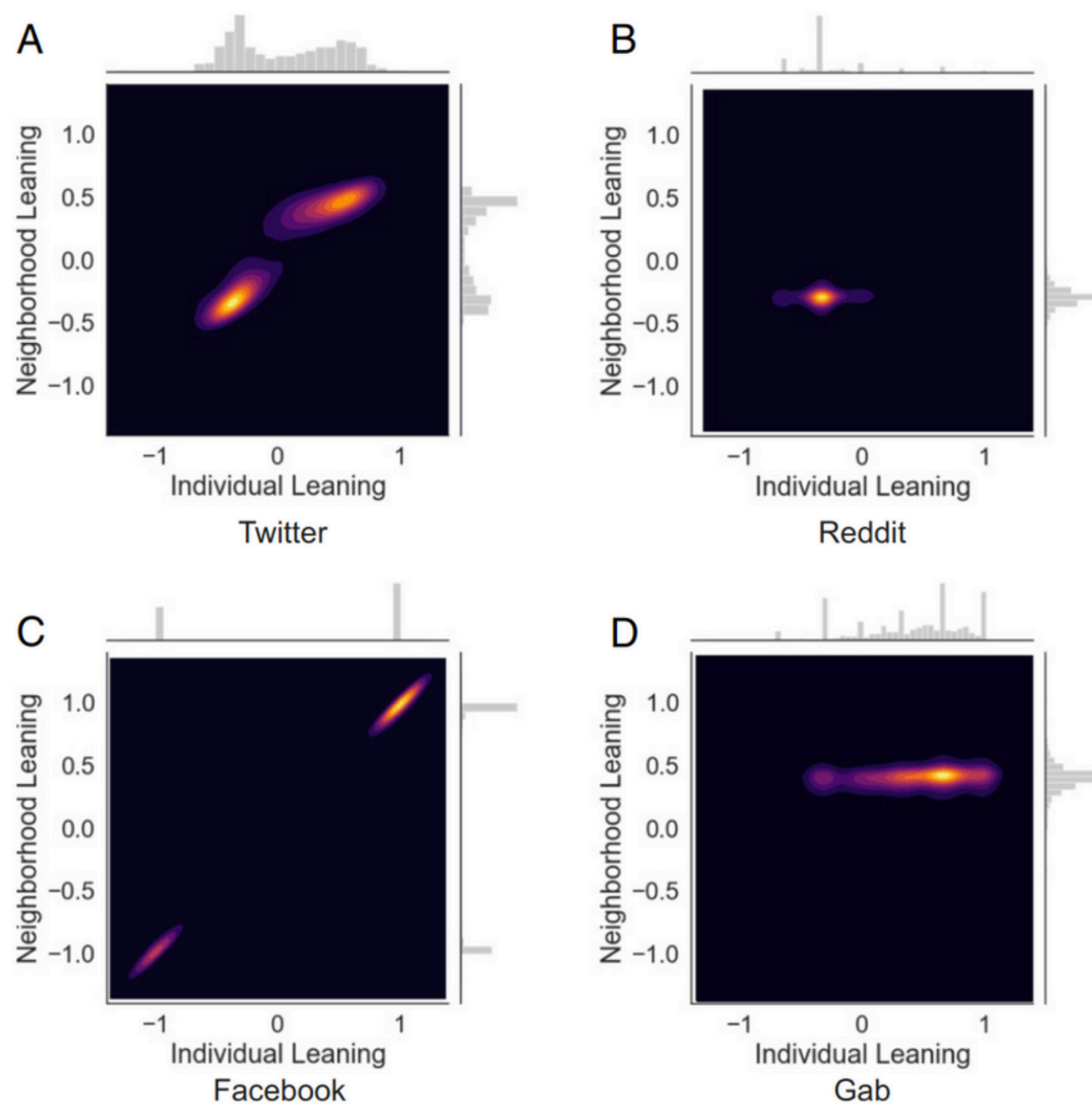
- **Facebook and Twitter:** Communities span the entire ideological spectrum but tend to be internally homogeneous, with some displaying strong polarization.
- **Reddit and Gab:** Communities do not cover the full spectrum, and most exhibit similar ideological leanings, with a pronounced lack of centrist communities.




Measuring Eco Chambers

Eco chambers are quantified by measuring the average leaning of a user's neighbors, which shows:

- **Facebook and Twitter:** Strong correlation between individual and neighborhood leanings, indicating the presence of highly segregated echo chambers.
- **Reddit and Gab:** A single, concentrated cluster. Users on Reddit lean predominantly left, while those on Gab lean right



A network diagram with nodes and edges on a blue background. The nodes are represented by small circles, some of which are black and others are light gray. The edges are thin lines connecting the nodes, forming a complex web. The text is centered over this network.

Spreading of (Mis)Information

Misinformation and Disinformation

The rapid spread of information online has made it easier for false or misleading content to reach large audiences

- **Misinformation:** Incorrect or misleading information shared without malicious intent.
- **Disinformation:** Deliberately false or manipulated information created and spread with the intent to deceive.

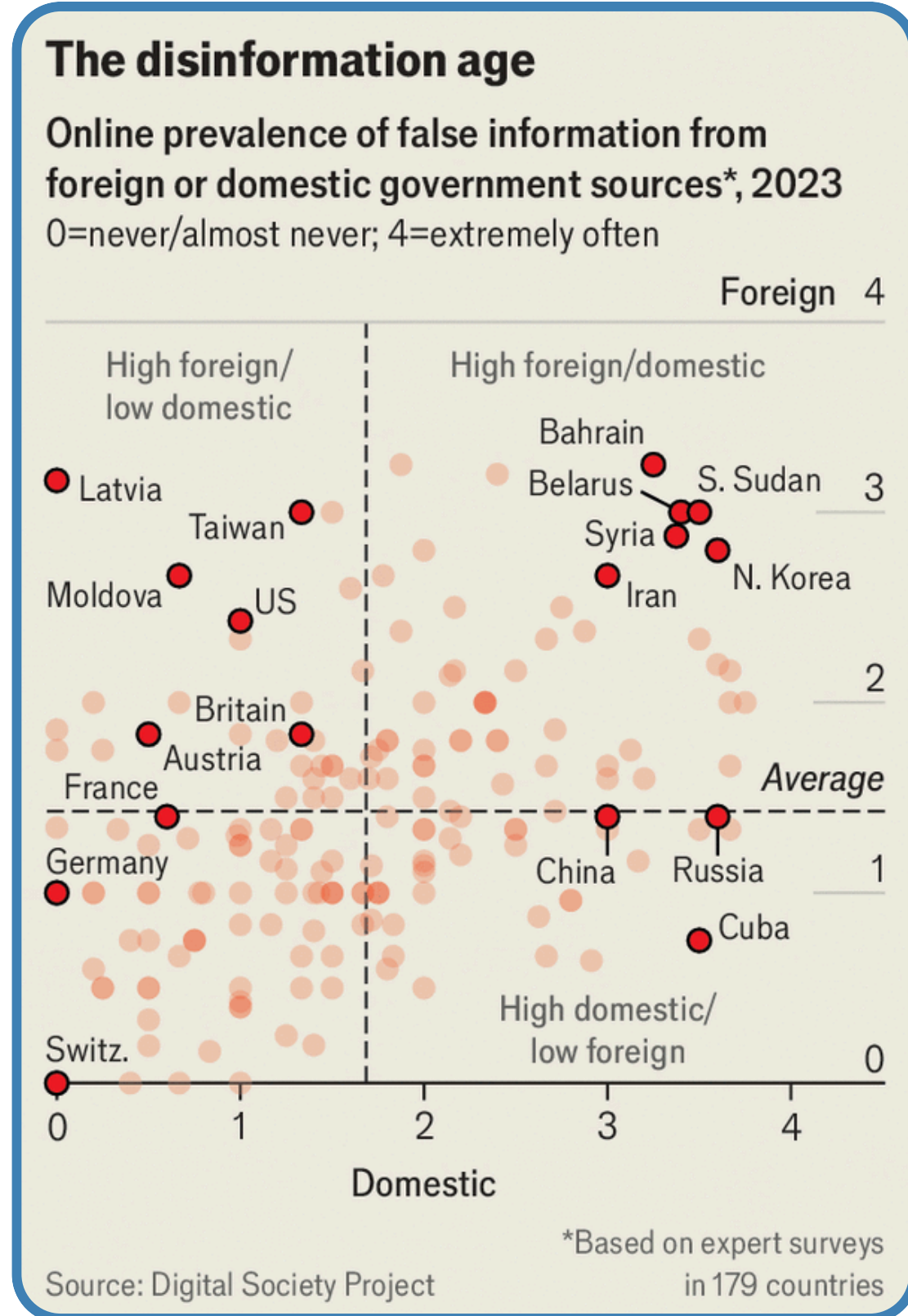
Social media platforms play a crucial role in amplifying both types.



A Global Problem

The spread of misinformation and disinformation poses significant challenges worldwide

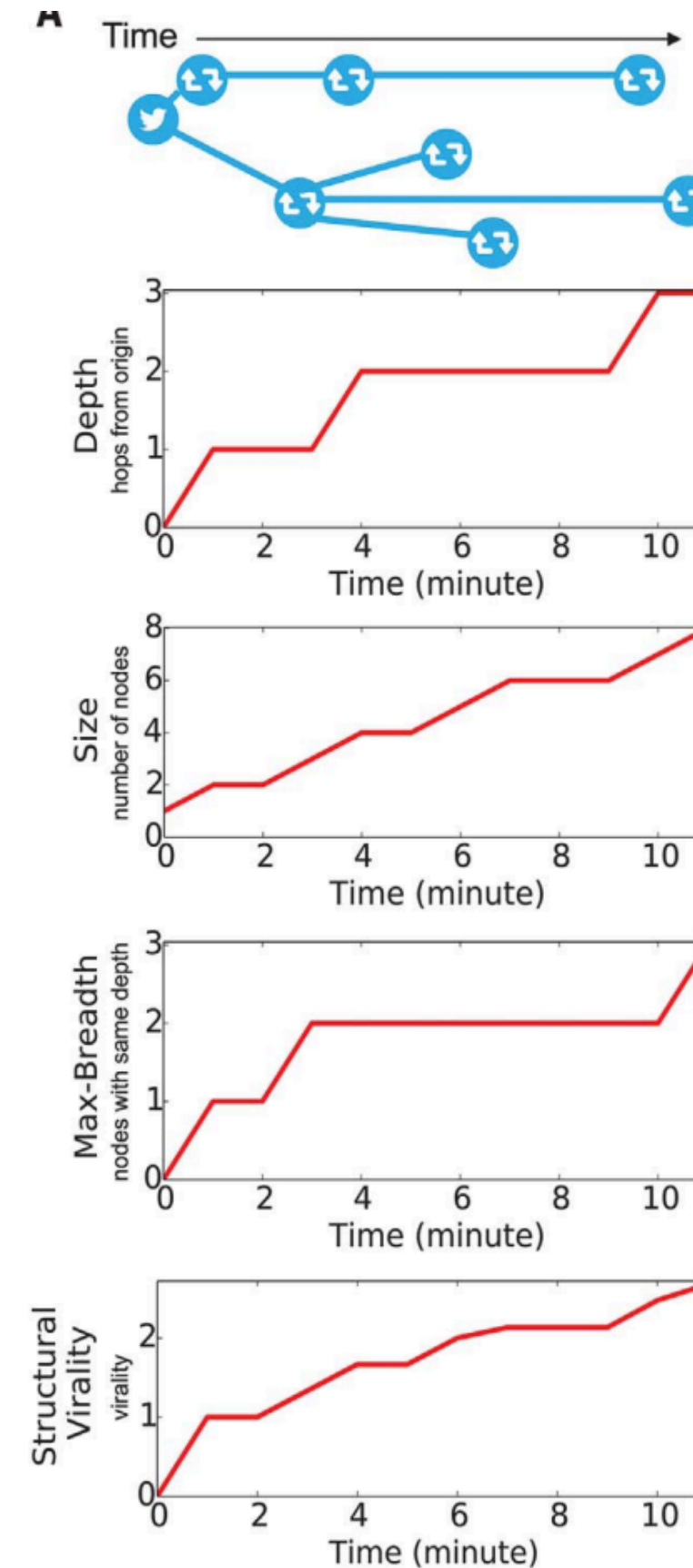
- A recent example is Romania's 2024 presidential election
- the Constitutional Court annulled the first round due to allegations of Russian interference
- Reports indicated that a coordinated online campaign, particularly on TikTok, was used to promote a far-right, pro-Russian candidate



Information Cascades

Information spreading can be studied looking at rumor cascade on twitter

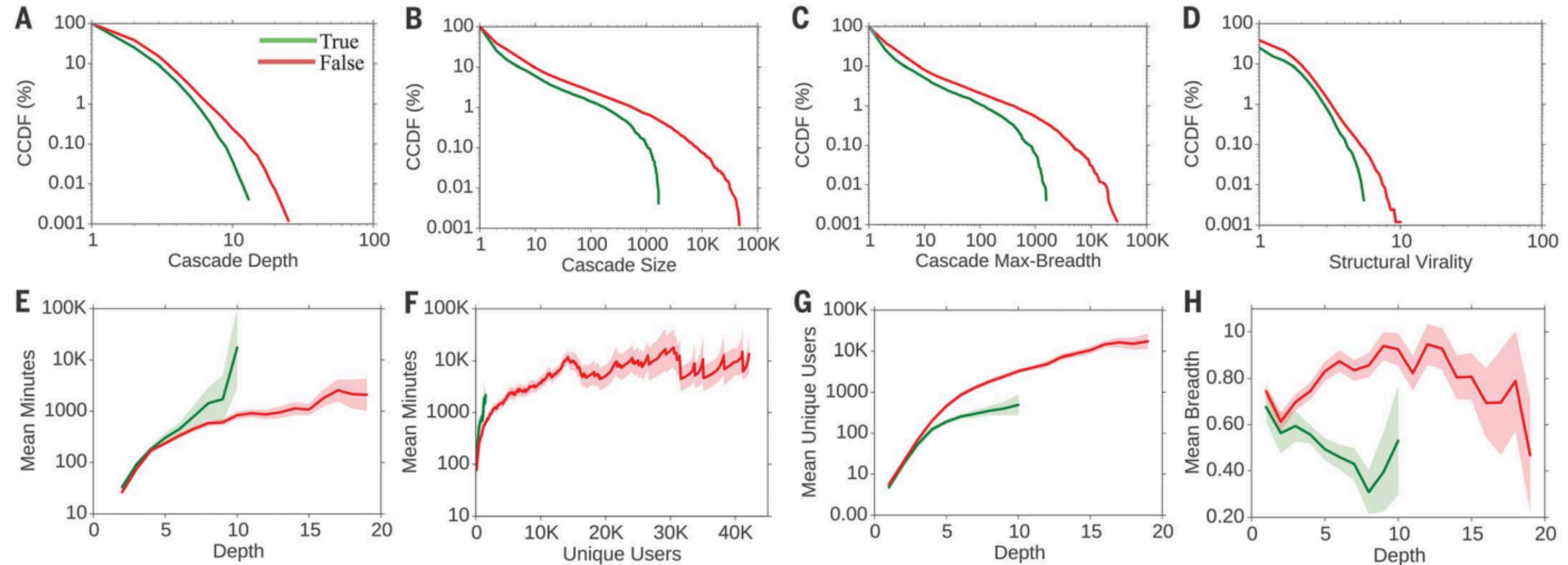
- they begins when a user posts a claim on Twitter
- Others propagate the rumor by retweeting it, creating an unbroken chain of diffusion
- Rumors are quantified by
 - depth (number of retweet hops)
 - size (total users involved)
 - maximum breadth
 - structural virality
- 126,000 rumor cascades from 2006 to 2017, fact-checked by six independent organizations



Vosoughi, Soroush, Deb Roy, and Sinan Aral. "The spread of true and false news online." *science* 359.6380 (2018): 1146-1151.

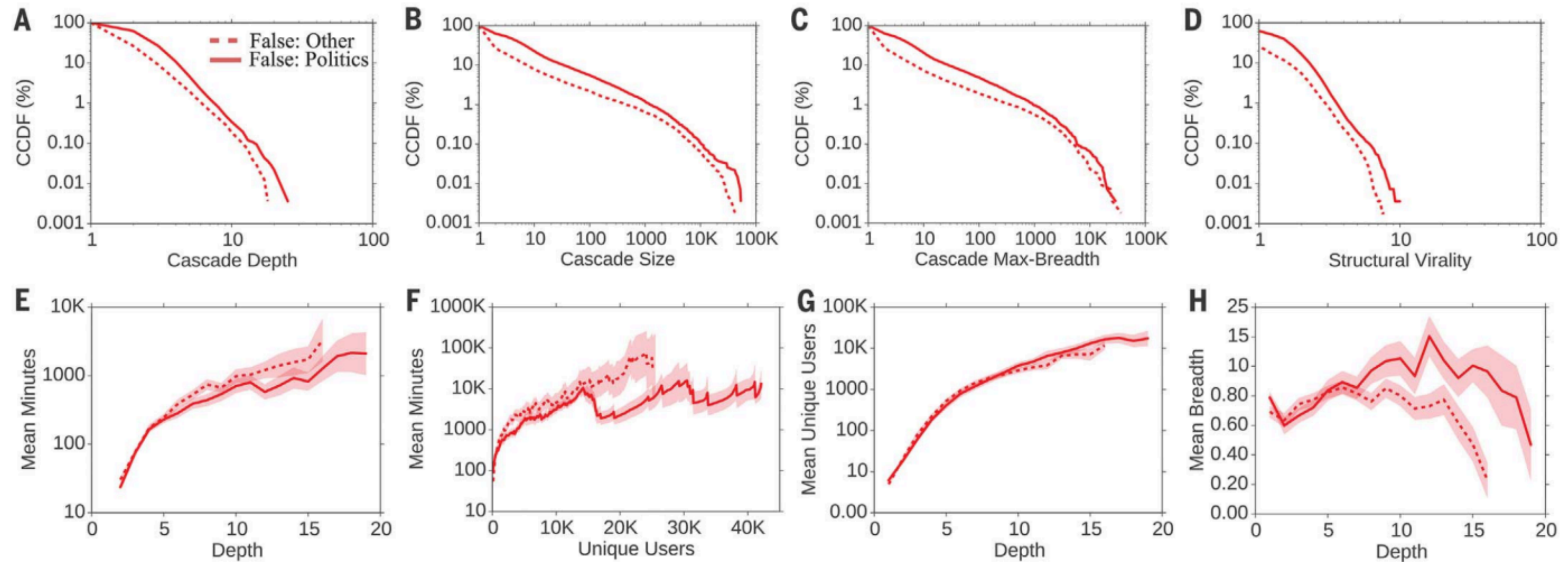
True vs False Rumors

All metrics show that false rumors tend to spread further, faster, and with greater reach compared to true information.

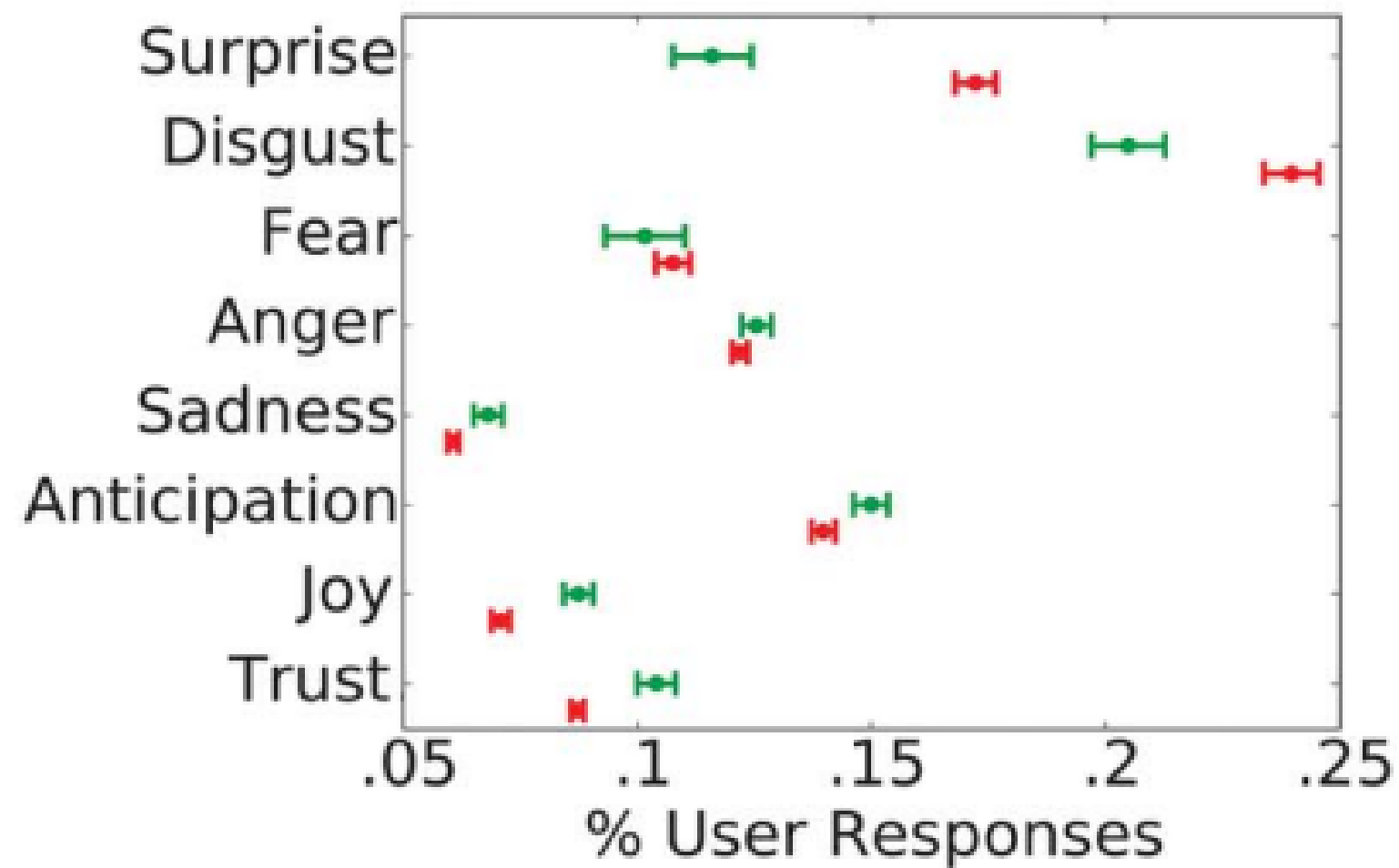


Political Rumors

This effect is even stronger for false political rumors, that that are even more viral than the other false rumors



Emotional Reaction to Rumors



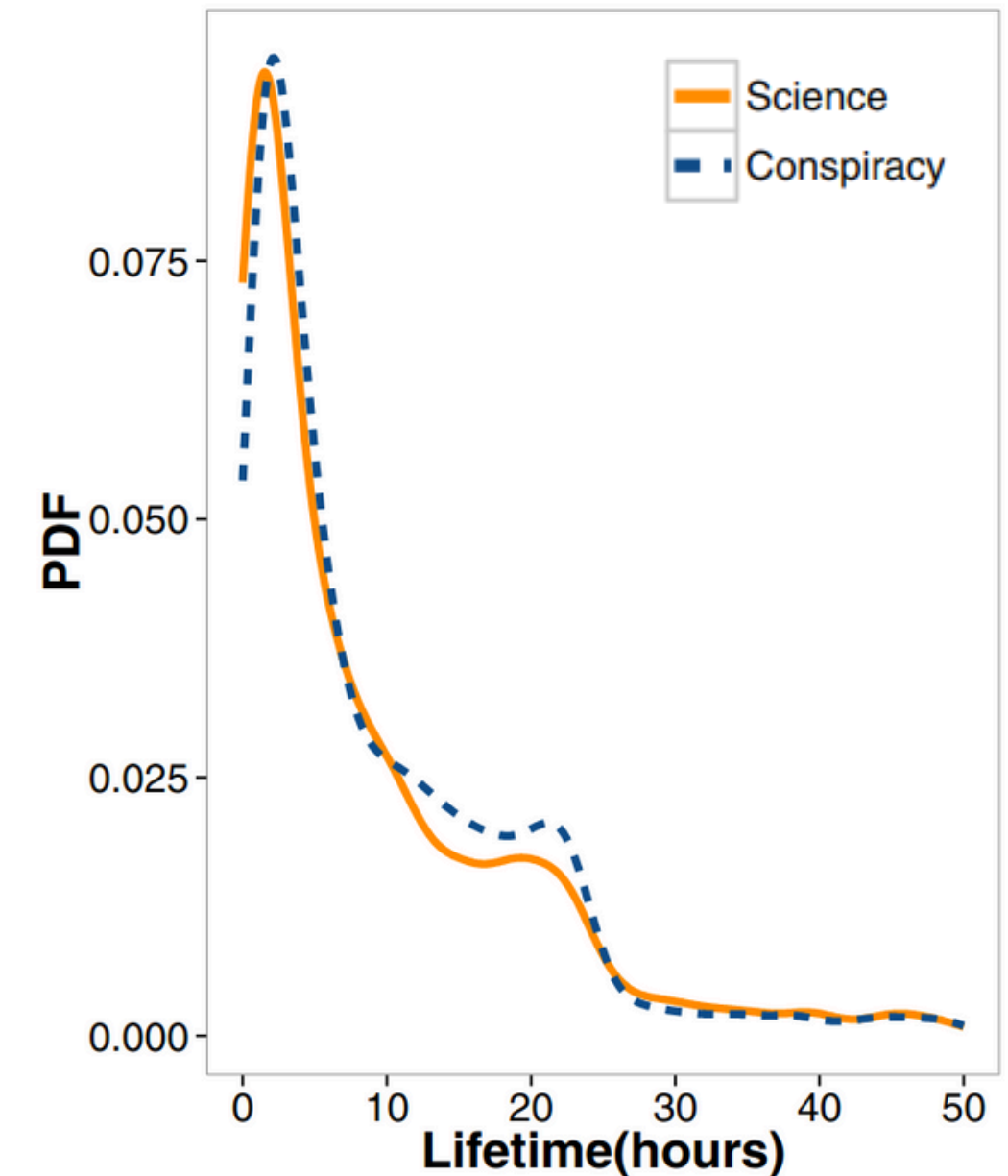
The emotional responses to true and false rumors reveal differences in how users perceive and engage with information.

- False rumors tend to evoke greater surprise and disgust, supporting the hypothesis that novelty plays a role in their widespread diffusion
- True rumors evoke more expressions of sadness, anticipation, joy, and trust

Science vs Conspiracy

The spread of science news and conspiracy theories on social media reveals distinct yet overlapping patterns.

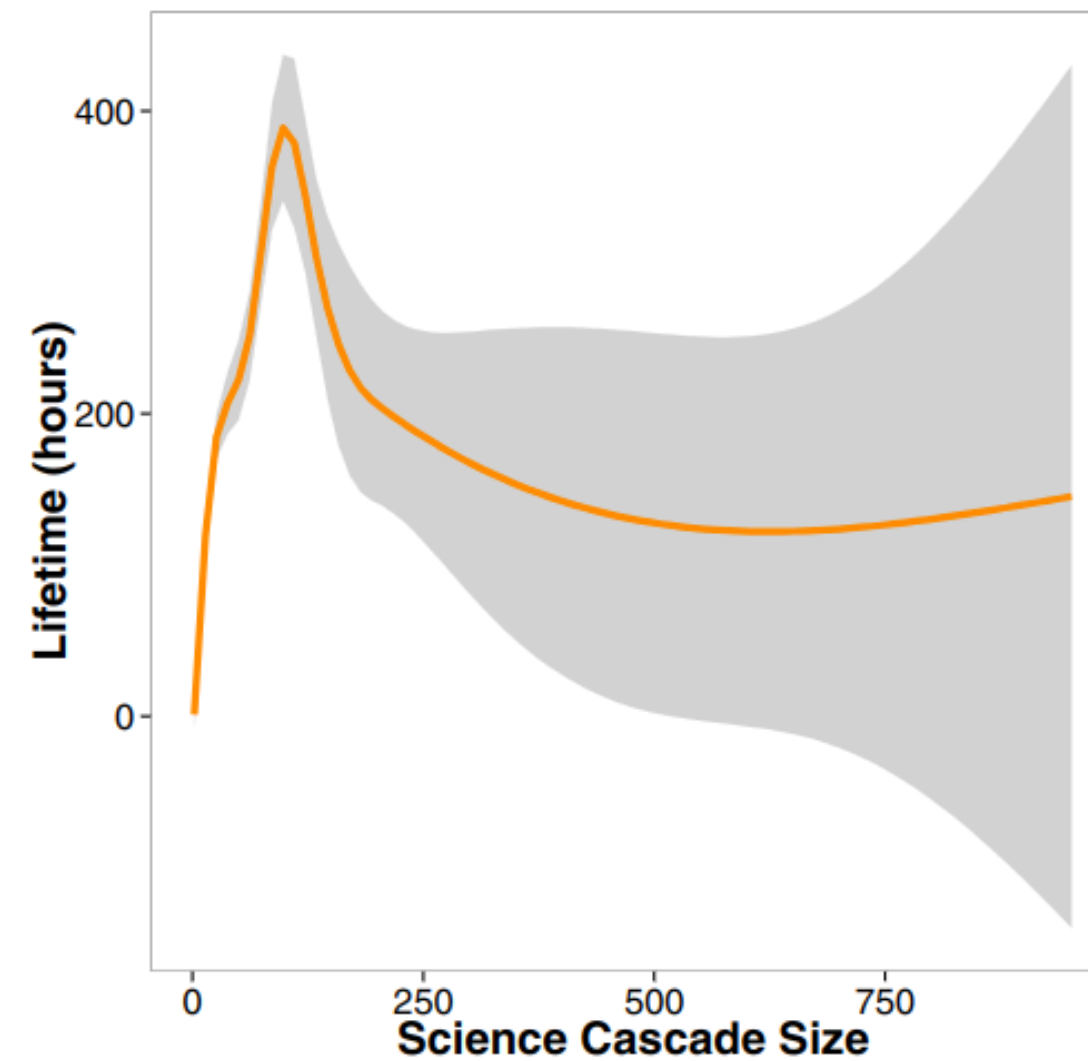
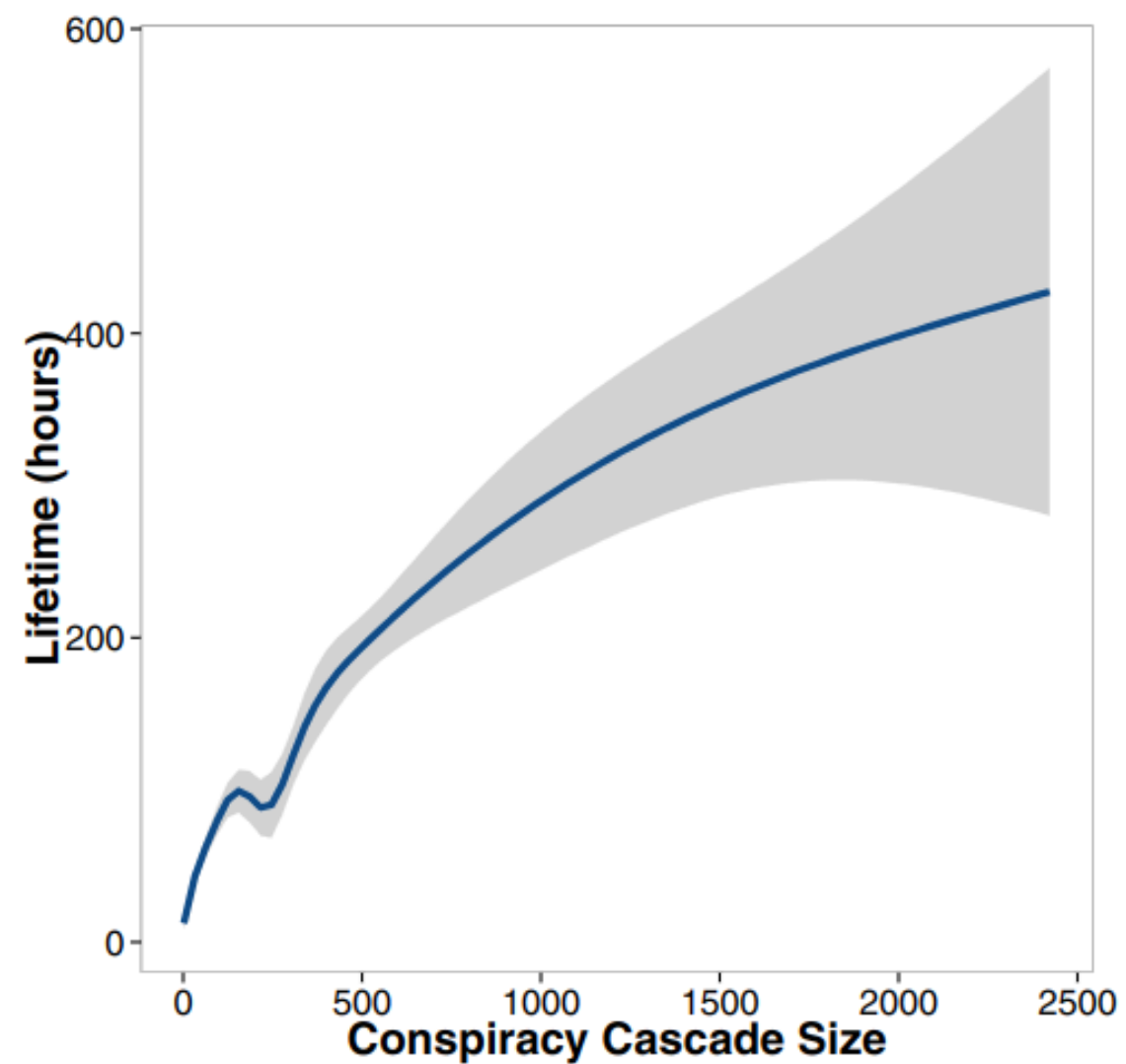
- analysis of 67 public Facebook pages, 32 conspiracy, 35 science
- both science and conspiracy posts exhibit similar temporal sharing patterns, with peaks at 1-2 hours and ~20 hours
- this indicates a rapid diffusion followed by sustained engagement.
- science news tends to have a slightly longer diffusion span



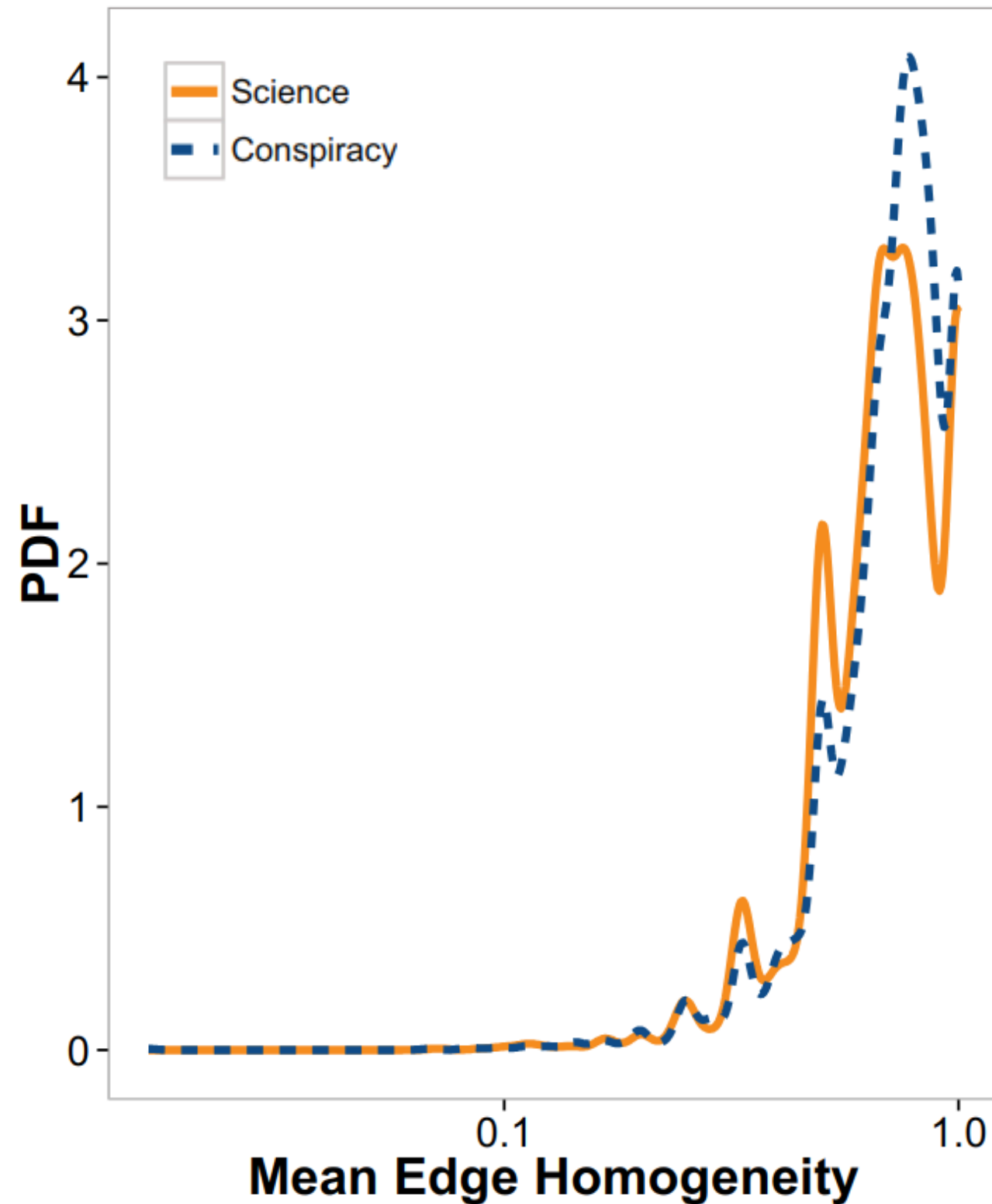
Del Vicario, Michela, et al. "The spreading of misinformation online." Proceedings of the national academy of Sciences 113.3 (2016): 554-559.

Cascade Size and Lifetime

For science news lifetime peaks in correspondence to a cascade size value of ≈ 200 , and higher cascade size values correspond to high lifetime variability. For conspiracy-related content the lifetime increases with cascade size.



Edge Homogeneity



information predominantly spreads within homogeneous clusters, reinforcing the concept of echo chambers.

- The majority of links between users sharing content are homogeneous
- Information diffusion primarily occurs within ideologically aligned communities
- The probability of sharing content across diverse groups is low

A network diagram with nodes and connecting lines, overlaid on a blue background. The nodes are represented by small circles, some of which are black and others are light grey. The lines connecting them are thin and light grey. The overall structure is a complex web of interconnected points.

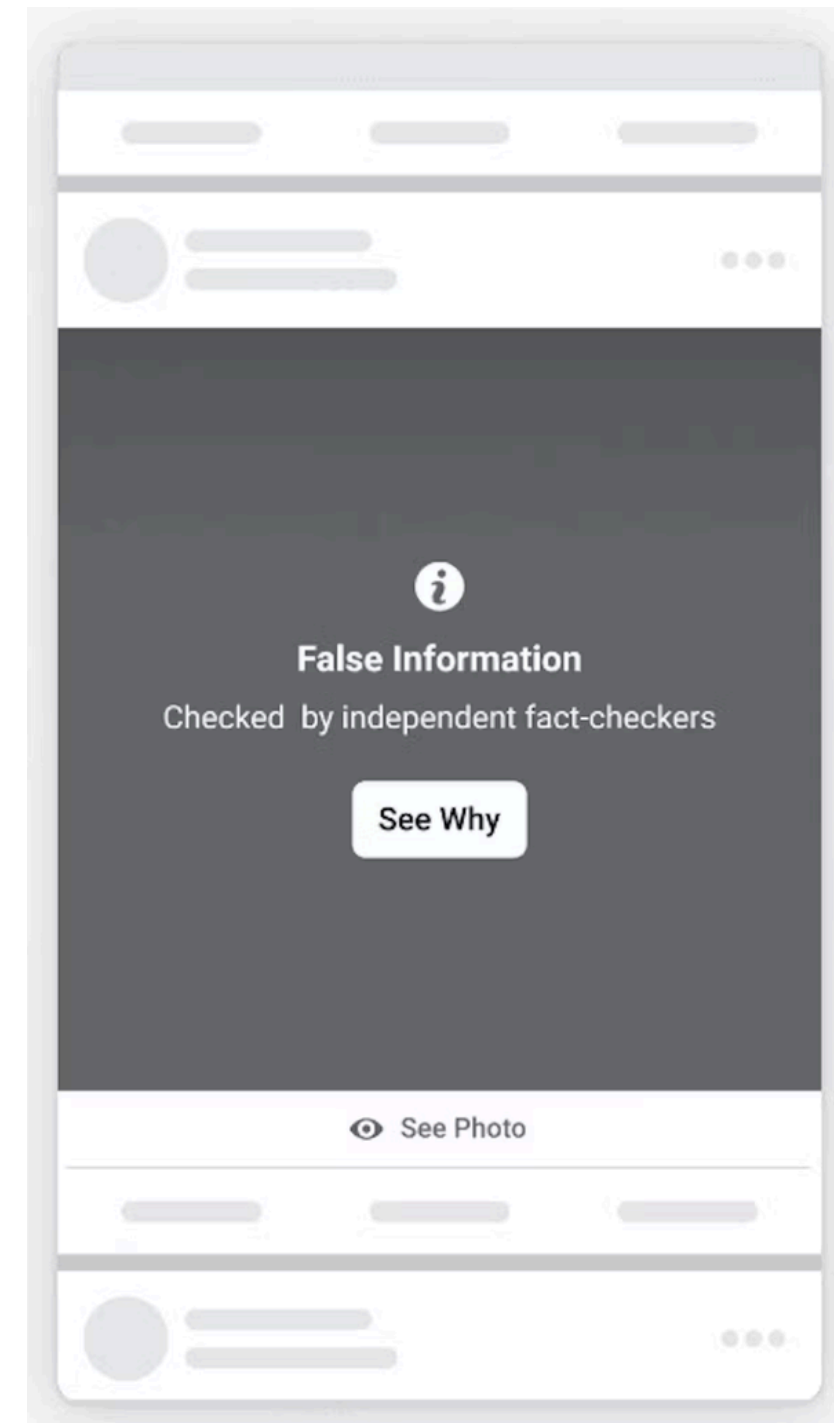
Online Debunking

The Death of Fact-Checking

Fact-checking has long been a critical tool in combating misinformation

- Recently major platforms such as Meta and X abandoned traditional fact-checking
 - In early 2025, Meta announced the discontinuation of its third-party fact-checking partnerships
 - Following Elon Musk's acquisition, X drastically reduced its moderation efforts

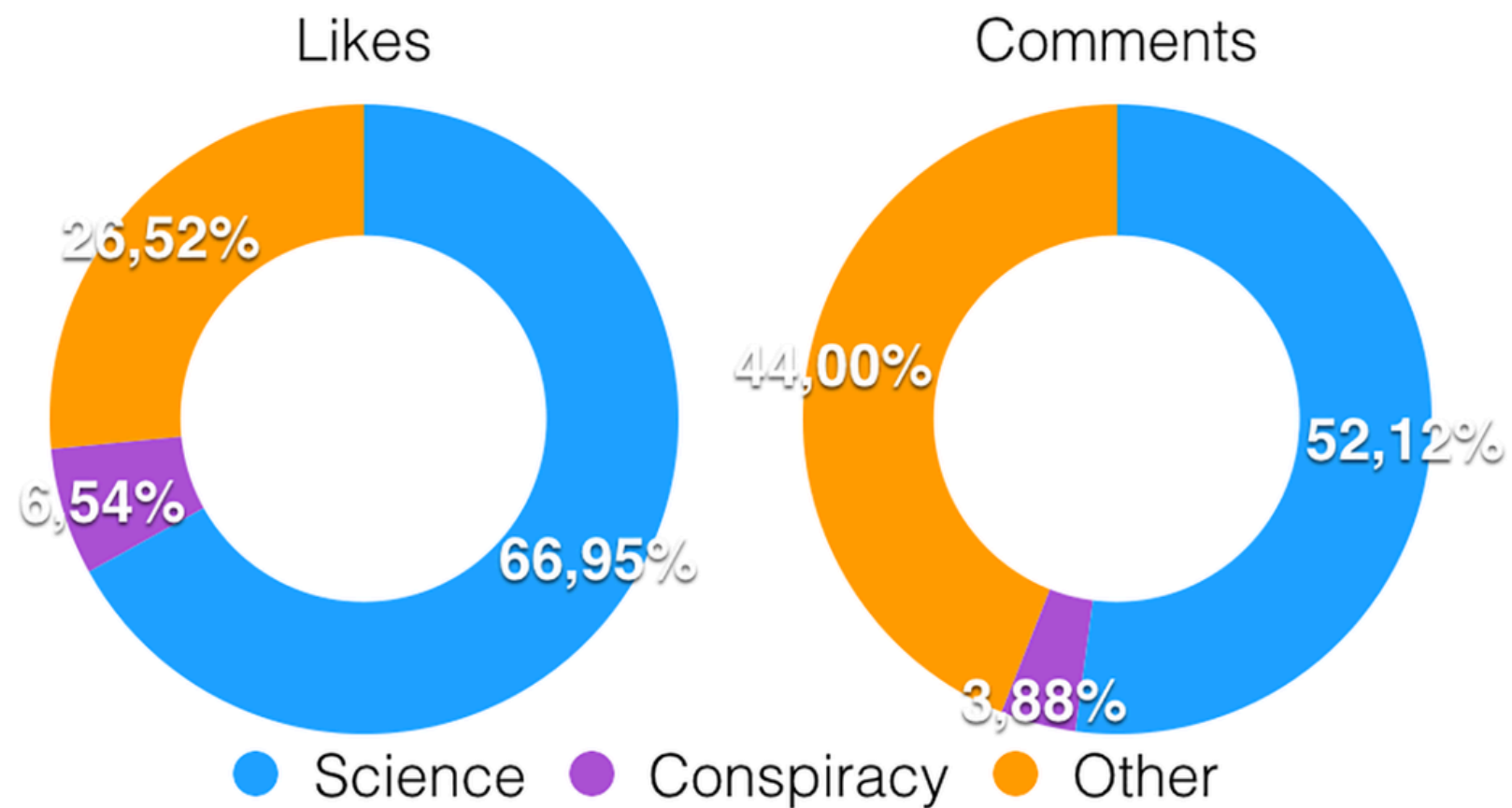
But how effective is fact checking?



Who is Reached by Debunking

The majority of interactions with debunking posts come from users already polarized towards science.

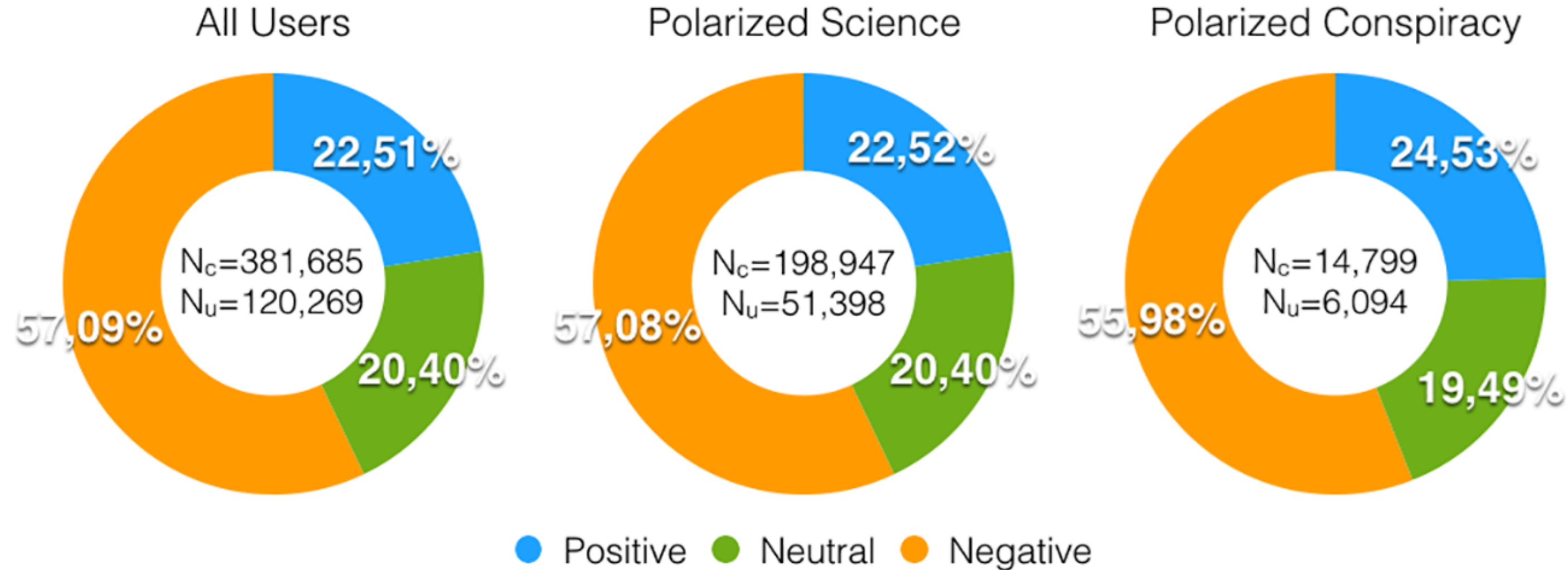
- 66.95% of likes and 52.12% of comments are from scientifically polarized users.
- Users polarized towards conspiracy theories contribute only 6.54% of likes and 3.88% of comments,
- Out of nearly 9.8 million polarized conspiracy users, only 117,736 interacted with debunking posts at least once,



Zollo, Fabiana, et al. "Debunking in a world of tribes."
PloS one 12.7 (2017): e0181821.

Sentiment of Comments

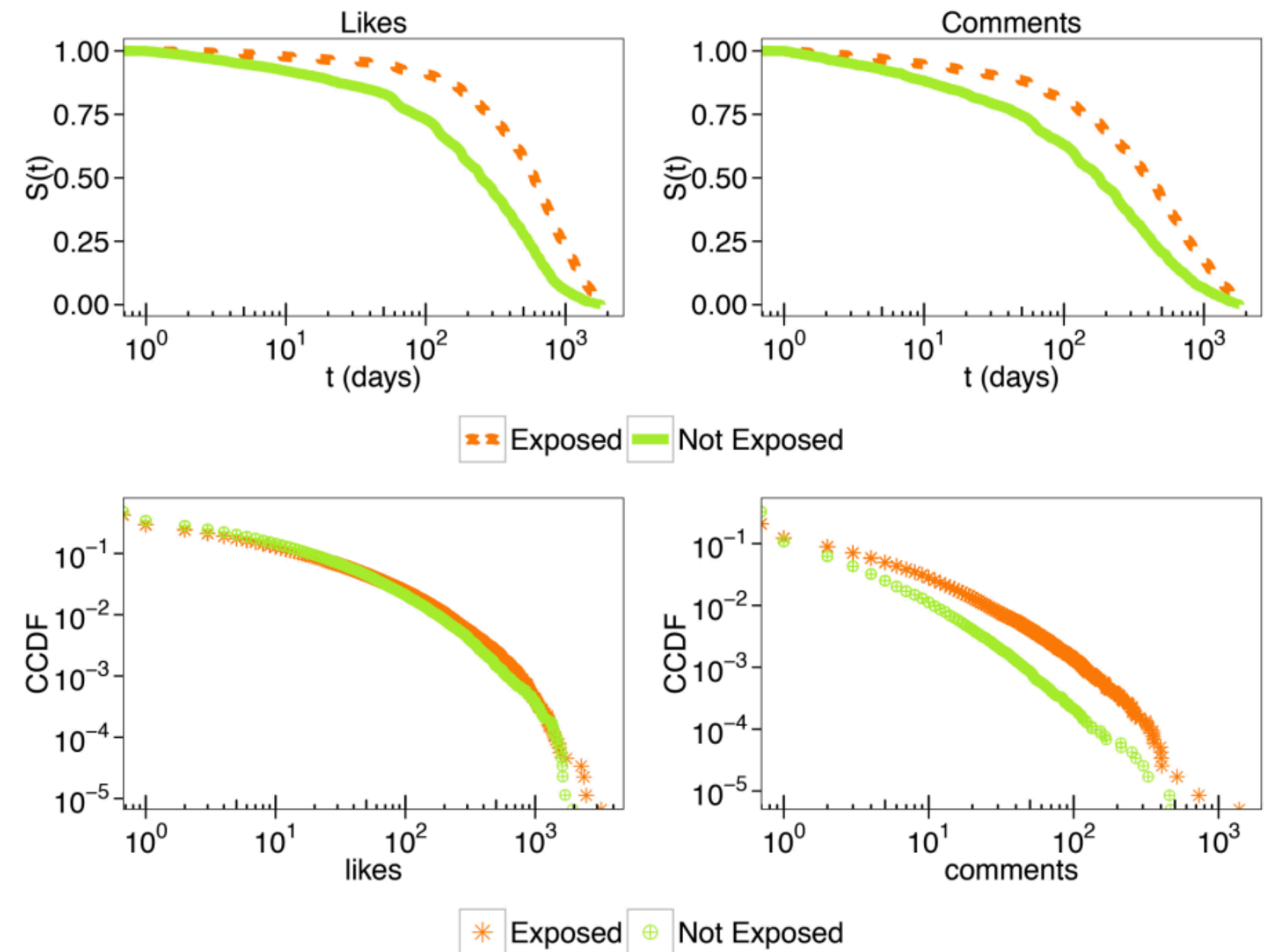
Debunking posts comments are generally negative, regardless of users' polarization. This suggests that debunking efforts often face skepticism and resistance from users across different echo chambers.



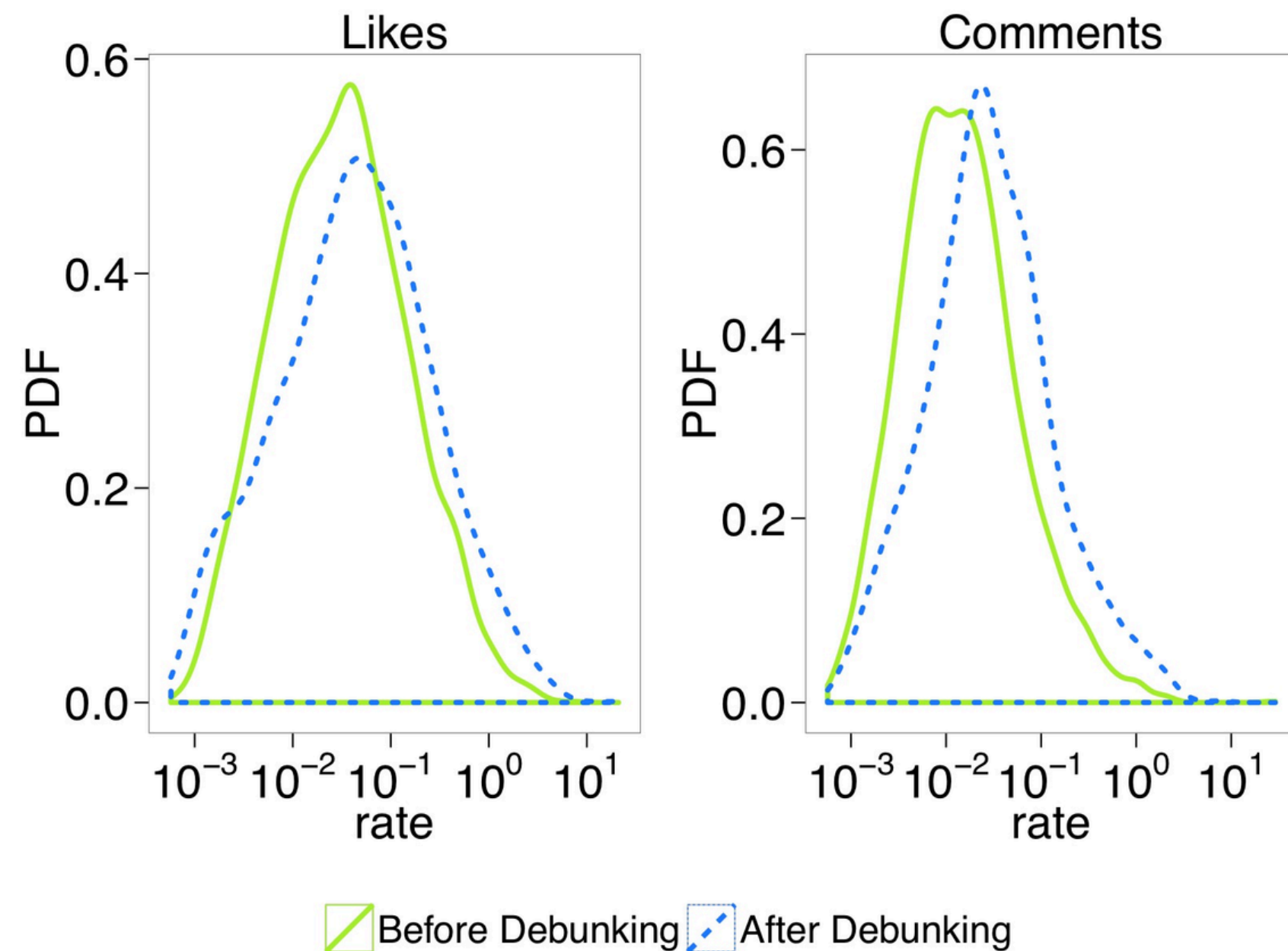
Is Debunking Effective?

A small fraction of users from the conspiracy echo chamber engage with debunking content. The analysis reveals that

- Users who comment on debunking posts are more likely to continue interacting with conspiracy content over time
- These users exhibit a slightly higher commenting activity overall, suggesting they are more engaged in online discussions



Probably **Not That Much**



Authors tested the behavior before and after the first interaction with debunking posts

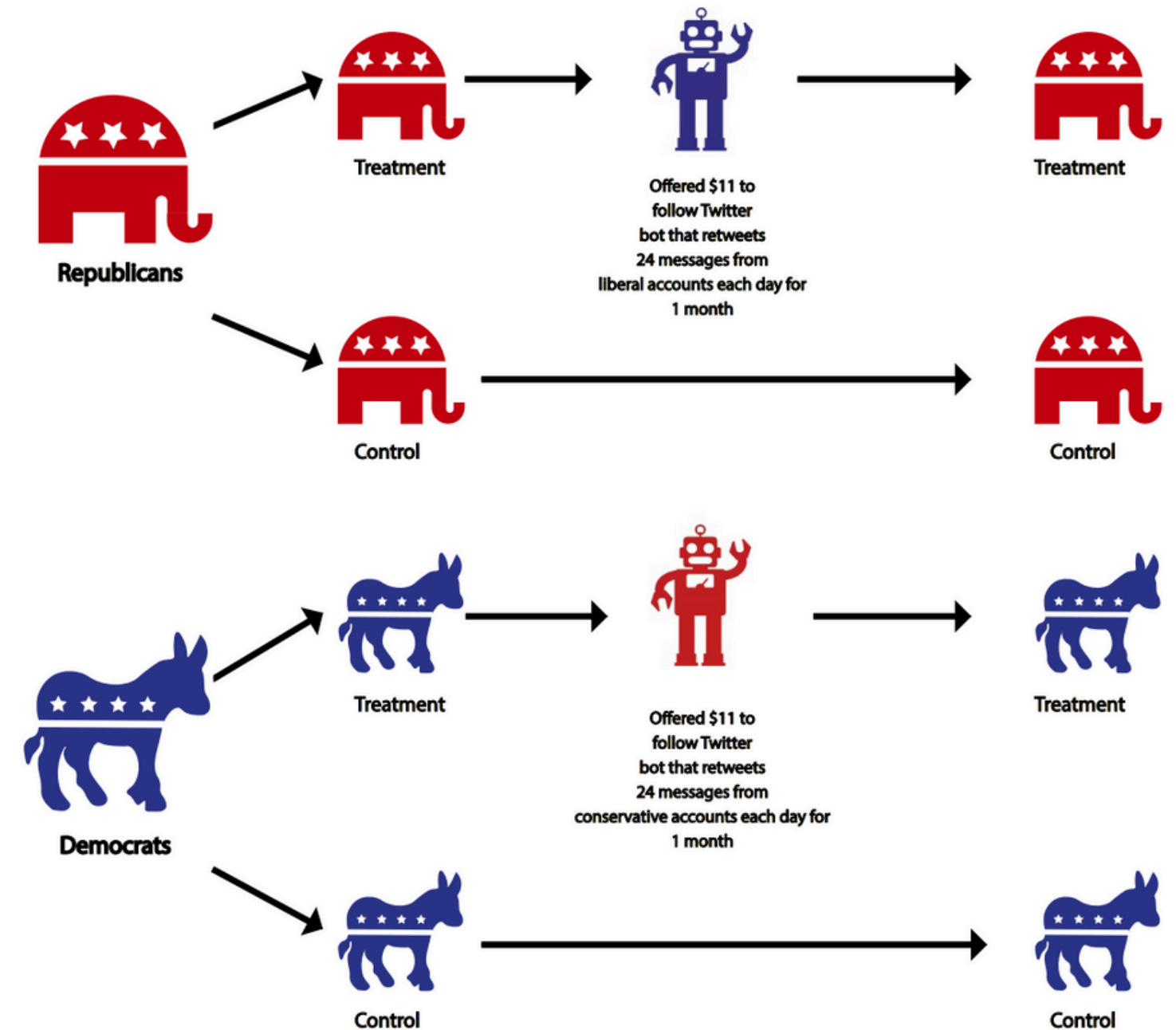
- Users' liking and commenting rates on conspiracy posts increase after their initial engagement with debunking content
- Users not exposed to debunking are 1.76 times more likely to stop interacting with conspiracy content compared to those who engage with debunking posts.

These results question the actual effectiveness of debunking

Exposure to Opposing Views

The effect of opposite perspective on users' ideology is non trivial. To investigate this in a study on Twittwe

- Participants, identified as Republicans or Democrats, were randomly assigned to follow Twitter bots
- Bots retweeted content from political figures with opposing ideologies
- Over one month, participants' engagement with the content was monitored, and their political attitudes were surveyed before and after exposure

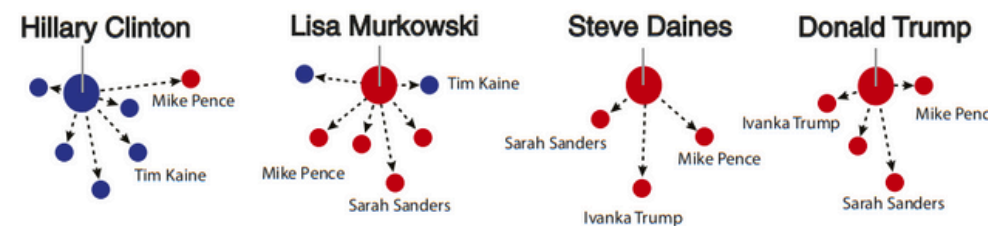


Bail, Christopher A., et al. "Exposure to opposing views on social media can increase political polarization." *Proceedings of the National Academy of Sciences* 115.37 (2018): 9216–9221.

How the Bots Function

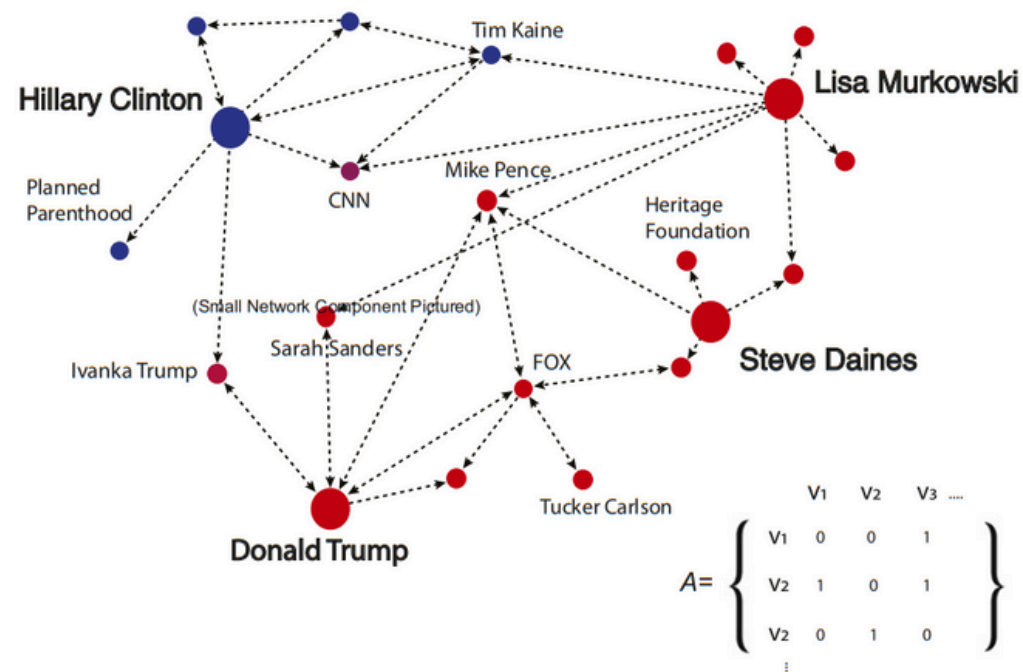
Elected Officials		Presidential Candidates	
Lisa Murkowski (R-AK)	@lisamurkowski	Ben Carson	@RealBenCarson
Don Young (R-AK)	@repdonyoung	Hillary Clinton	@HillaryClinton
Jon Tester (D-MT)	@SenatorTester	Carly Fiorina	@CarlyFiorina
Steve Daines (R-MT)	@stedaines	Lawrence Lessig	@Lessig
Mike Enzi (R-WY)	@SenatorEnzi	Martin O'Malley	@martinomalley
John Barrasso (R-WY)	@SenJohnBarrasso	Donald Trump	@realDonaldTrump
...etc	...etc	...etc	...etc

1 Collect Twitter handles of 563 elected officials and presidential candidates.



2 Extract the names of all Twitter accounts that these 563 elected officials and presidential candidates follow (n=636,738).

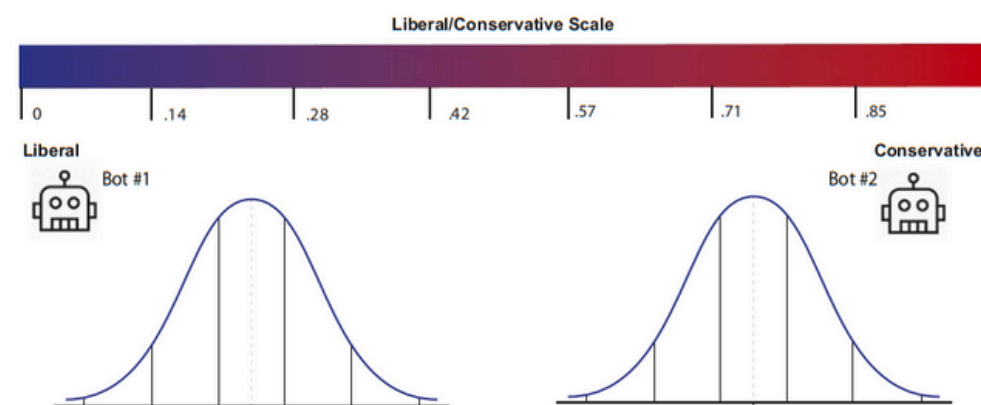
(Small Network Component Pictured)



3 Create directed network of all elected officials, presidential candidates, and everyone they follow; dropping non-elected officials with degree less than 15 as well as Twitter accounts from U.S. government agencies, for-profit corporations, and accounts that originate outside the U.S. (n=4,176).

4 Create adjacency matrix that describes following patterns of the 4,176 "opinion leaders" and conduct Correspondence Analysis. Adjust scores of accounts with large no. of followers (see Supp. Materials).

$$A = \begin{pmatrix} & V1 & V2 & V3 & \dots \\ V1 & 0 & 0 & 1 & \\ V2 & 1 & 0 & 1 & \\ V3 & 0 & 1 & 0 & \\ \vdots & & & & \ddots \end{pmatrix}$$



5 Use first principal component to create liberal/conservative ideology score for 4,176 opinion leaders.

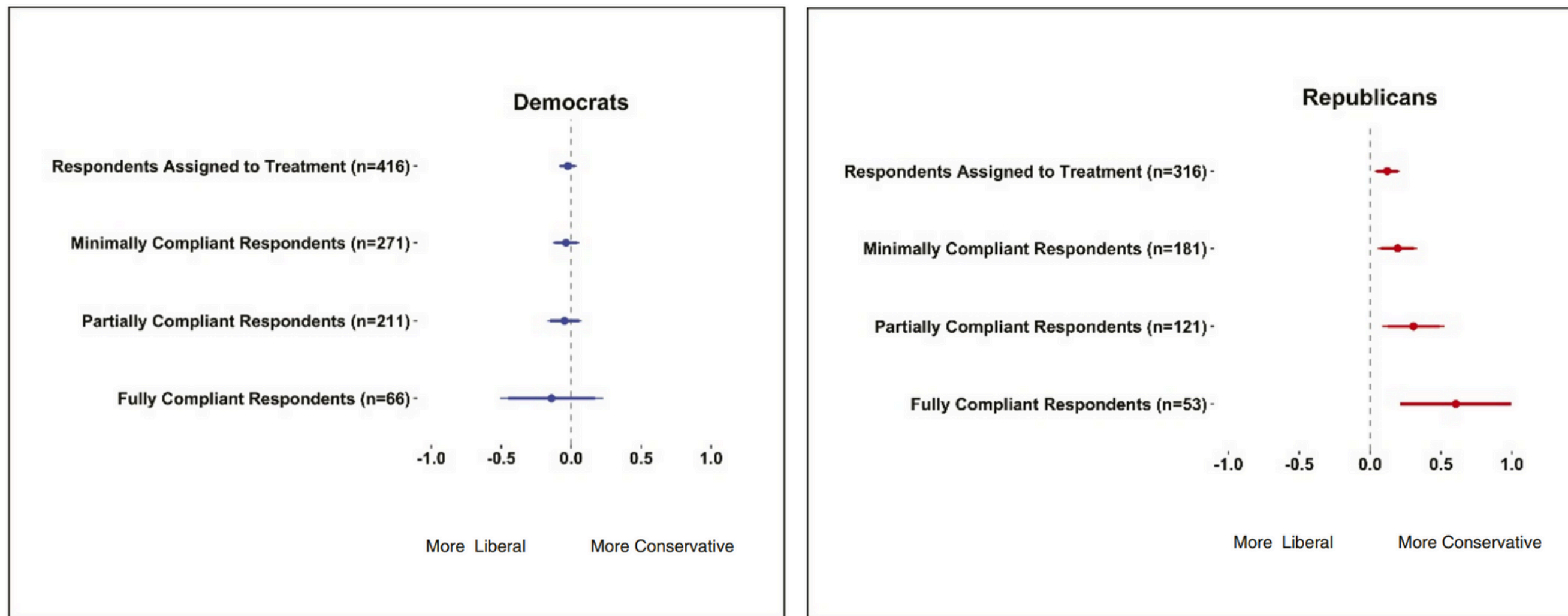
6 Create bots that tweet a random sample of tweets from the 1-3 (liberal) and 5-7 (conservative) quantiles of the distribution.

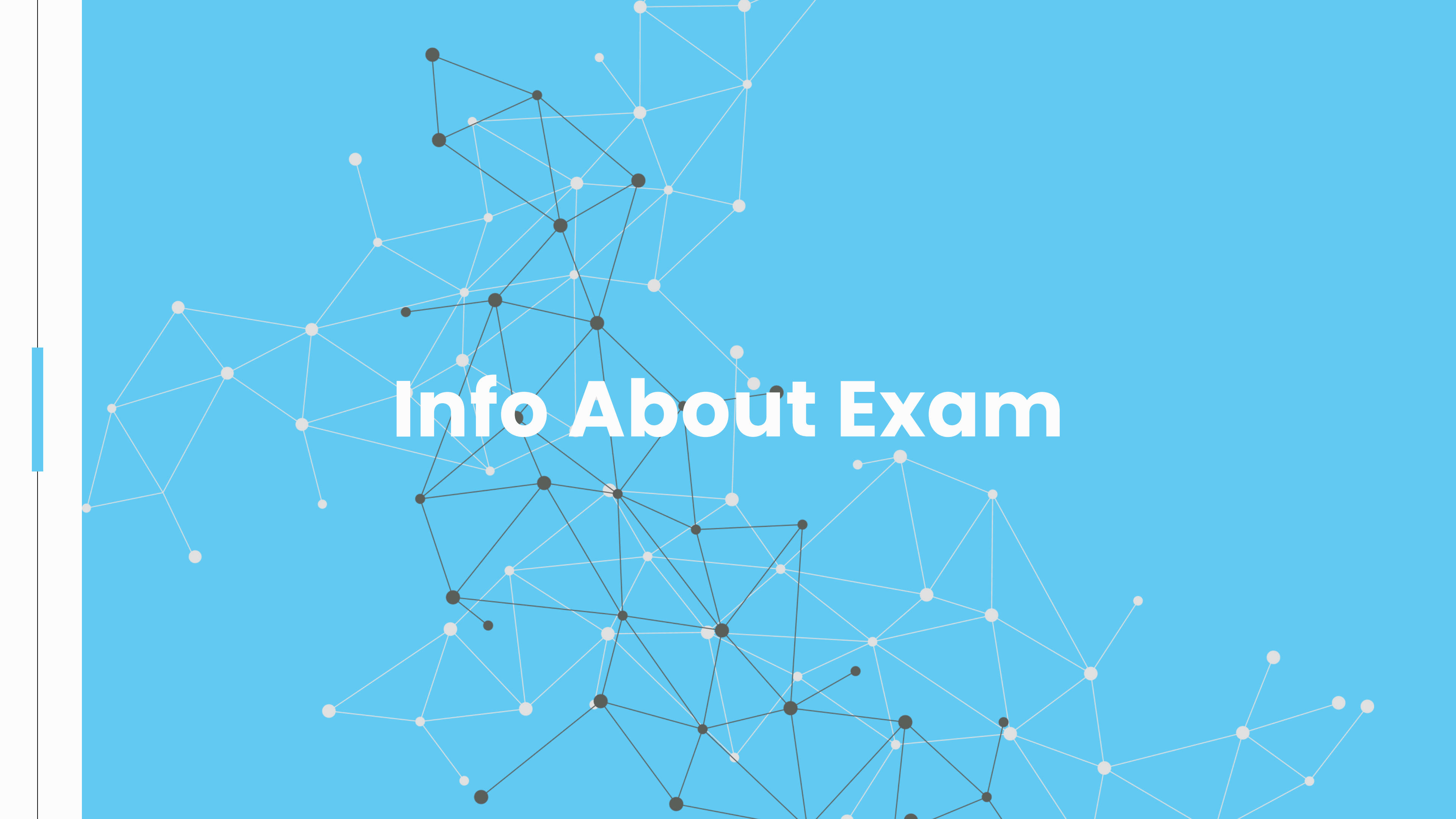
Researchers developed automated Twitter bots capable of retweeting messages from thousands of political opinion leaders

- bots were designed to expose participants to content from across the ideological spectrum
- tweets were selected using network analysis techniques to identify influential figures.
- Participants were unaware of the bots' ideological biases

Effect of Treatment

For Republicans, engaging with liberal content resulted in a notable shift toward more conservative views, demonstrating a strong backfire. On the other hand, Democrats showed minimal changes after exposure to conservative content, indicating that such interactions might have limited influence.



A network diagram with nodes and connecting lines, overlaid on a blue background. The nodes are represented by small circles, some of which are black and others are light grey. The lines connecting them are thin and light grey. The overall structure is a complex, interconnected web of nodes and edges, suggesting a network or data structure.

Info About Exam

Paper/Dataset and Exam

Remember to send me the name of the paper/dataset you want to work on!

- you can find them at <https://giordano-demarzo.github.io/teaching/network-science/>
- you can also propose a paper/dataset

There will be 3 exam periods:

- February
- End of March
- Begin of April

You can write me an email with when you would like to do the exam (send 2/3 possible days) and we will organize

Remember to register for the exam on Zeus

Next Monday Lecture

Next Monday (03/02) you will present what you want to do for the exam

- you can use 1 or 2 slides
- you can use up to 5 minutes to describe what you intend to do
- you can ask questions if you have doubts about how to replicate something or about the data

You will not be evaluated for this presentation

The Exam

The course grade is based on:

- the student presentation (35%)
- the code (15%)
- and on the report (50%)

The report must be structured as a scientific paper and about 4/5 pages long

- Abstract
- Introduction
- Results/Main Analysis
- Discussion
- References and link to the code
- An appendix (up to 3 pages, optional)

The presentation should be around 15 minutes plus 5/10 minutes for questions and discussion. The code must be uploaded to github.

Conclusions

Polarization and Online Echo Chambers

Increasing levels of polarization, across multiple dimensions, are observed in society. This phenomenon is particularly strong on social networks, that are characterized by an echo chamber structure.

Spreading of (Mis)Information

Misinformation and disinformation are a serious threat to democracy. False news and rumors tend to spread more rapidly and deeply on online platforms. They mostly diffuse within echo chambers.

Online Debunking

Online giants recently abandoned fact checkers for different moderation strategies. Studies show that standard fact-checking posts have little effect and, if any, they tend to worsen the situation.

Quiz

- Do you know what a filter bubble is?
- What is the difference between filter bubbles and echo chambers?
- Which social network do you think is more polarized?
- Do you think you're enclosed in an echo chamber?
- What are some examples of false rumors that spread rapidly?
- Why is fact checking ineffective in your opinion?