ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Understanding and Solving Societal Problems with Modeling and Simulation

Lecture 5: Opinion Polarization

Dr. Michael Mäs

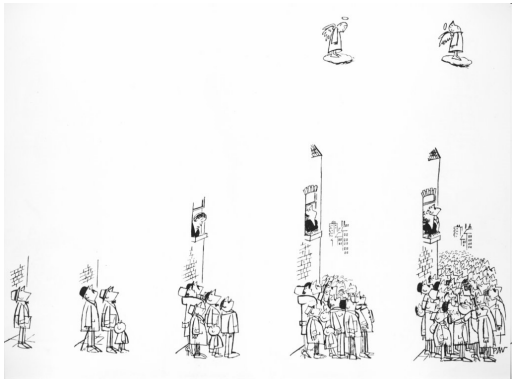
Aims of this lecture

- Understand “Abelson’s puzzle” of opinion polarization
- Understand classical models of social influence
- Understand existing approaches to opinion polarization and clustering of opinions
- Discuss ways to prevent opinion polarization

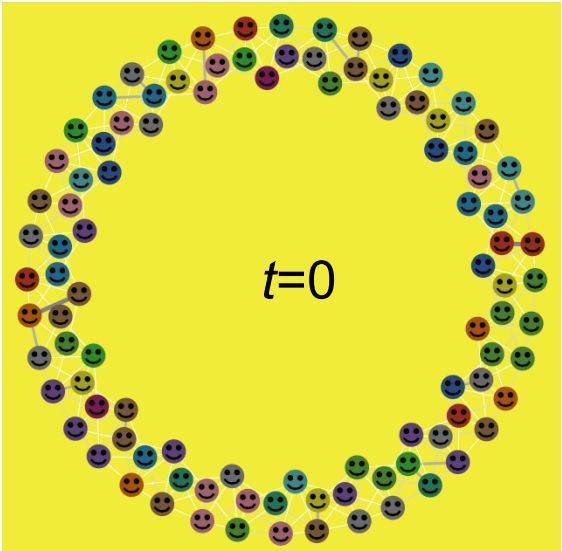
Classical models of social influence and Abelson's puzzle

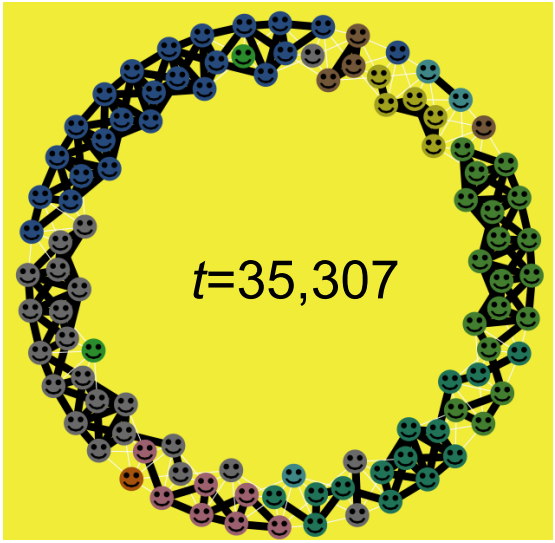
Two weeks ago: Axelrod's model of the dissemination of culture

Axelrod assumed homophily and social influence …



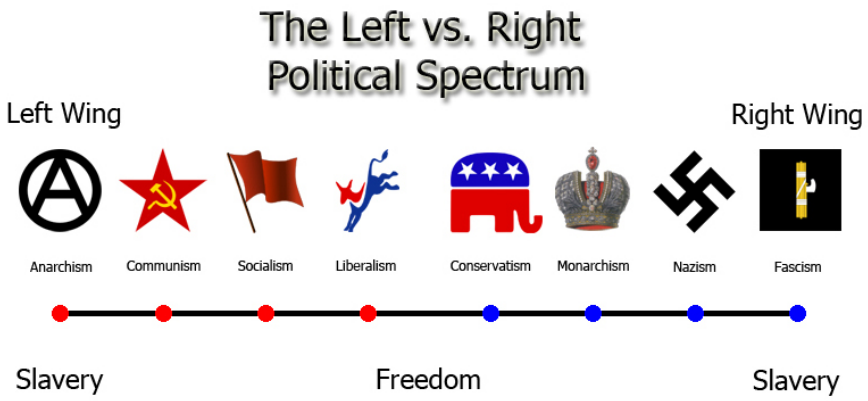
… and generated stable cultural diversity.

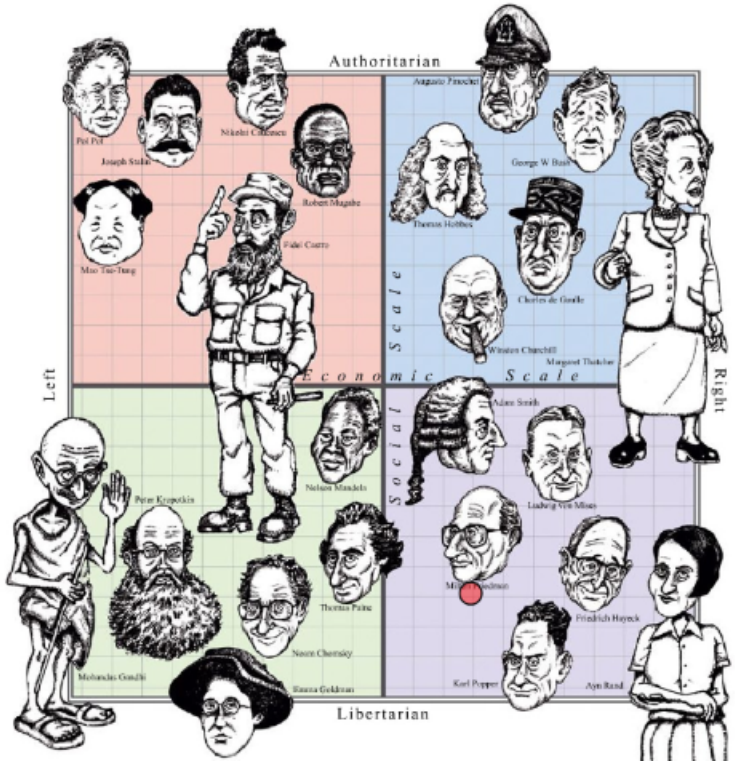




However, already in the 1950s models of social influence studied similar problems

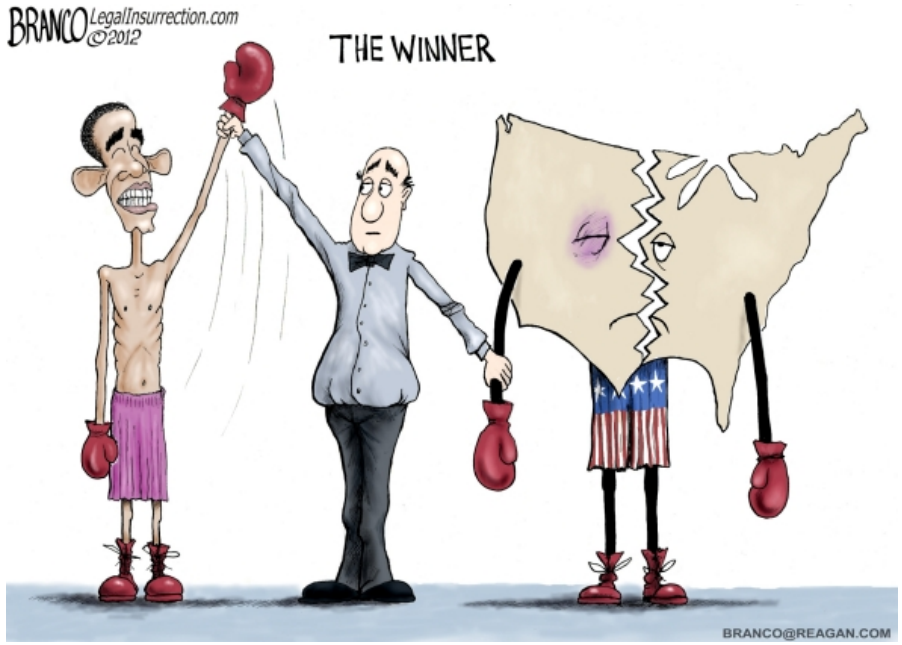
- Contrary to Axelrod's model, which assumes features to have a nominal scale, classical contributions are concerned with continuous scales.
- Actually, the many cultural features are best measured on continuous scales





- Examples:
  - Left vs. right scale
  - What is the best age for a woman to marry?

Polarization of continuous opinions is a big issue



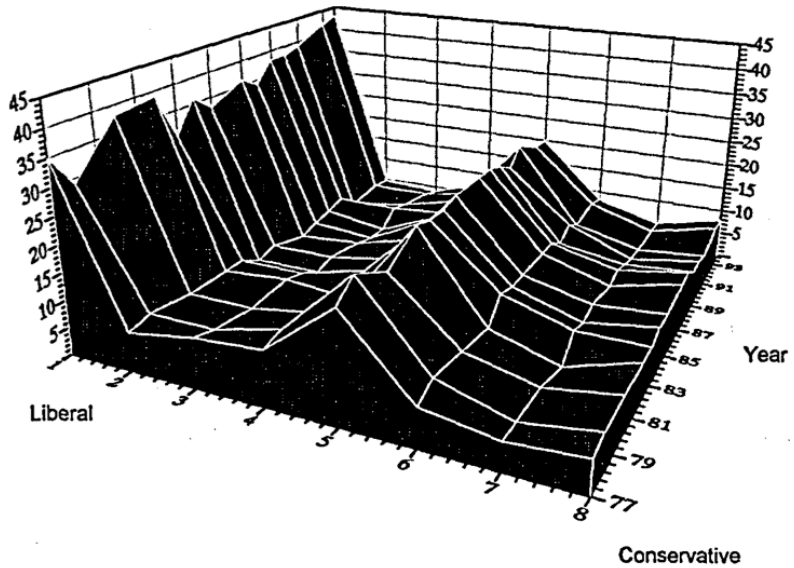


FIG. 4.—Distributions by year, attitudes toward abortion, full sample, GSS 1977–94.

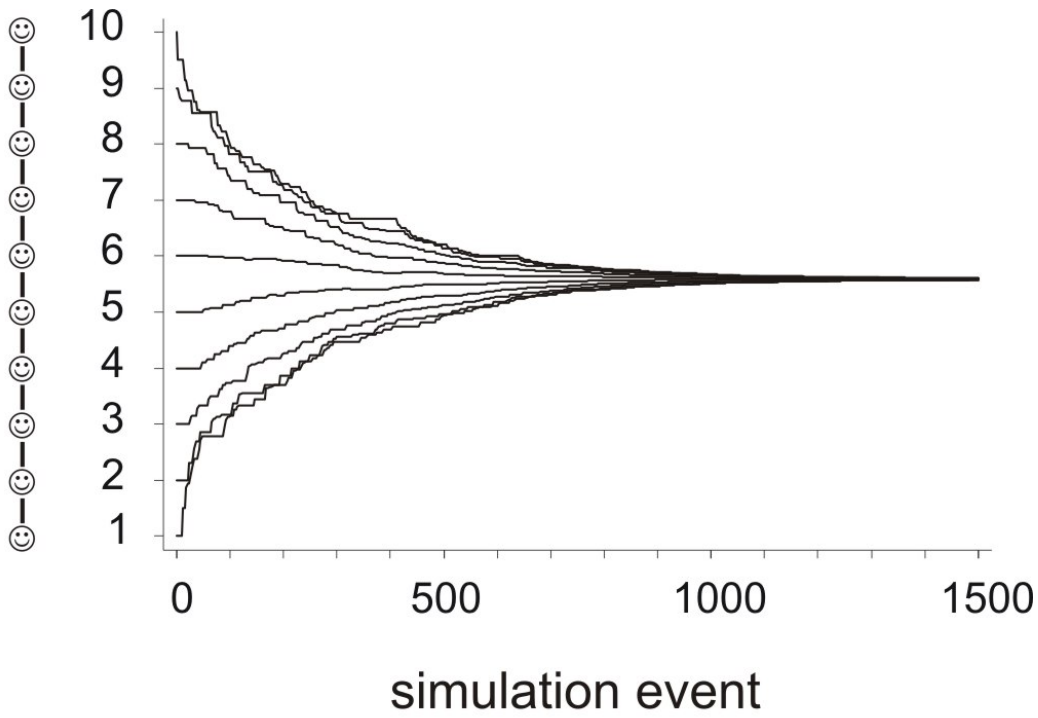
Source: DiMaggio 1996

Classical models of social influence

- Developed in the 1950's and 1960s by DeGroot, Lehrer and Wagner, Abelson, Harrary
- Core assumptions:

Classical models of social influence		Axelrod's model of cultural dissemination
Actors are influenced by network contacts, but not all contacts are equally influential	=	Actors are influenced by network contacts, but not all contacts are equally influential
Influence weights are fixed	≠	Interaction probability depends on similarity (homophily)
Continuous opinion scales	≠	Nominal opinion scales
Influence is implemented as averaging	≠	Influence is implemented as imitation

- Example:
  Assume a very sparse influence network, a line.
  Initially, agents hold opinions similar to their position on the line.
  Agents adopt opinions similar to average opinion of their contacts.



- Main outcome: As long as no subset of agents is completely cut-off from social influence, there will always be consensus

- Abelson: ”what on earth one must assume in order to generate the bimodal outcome of community cleavage studies?" (1964: 153)

Explanations of opinion polarization and opinion clustering

Discuss with your neighbor

What ingredients would you include to explain opinion diversity in settings where individuals influence each other.

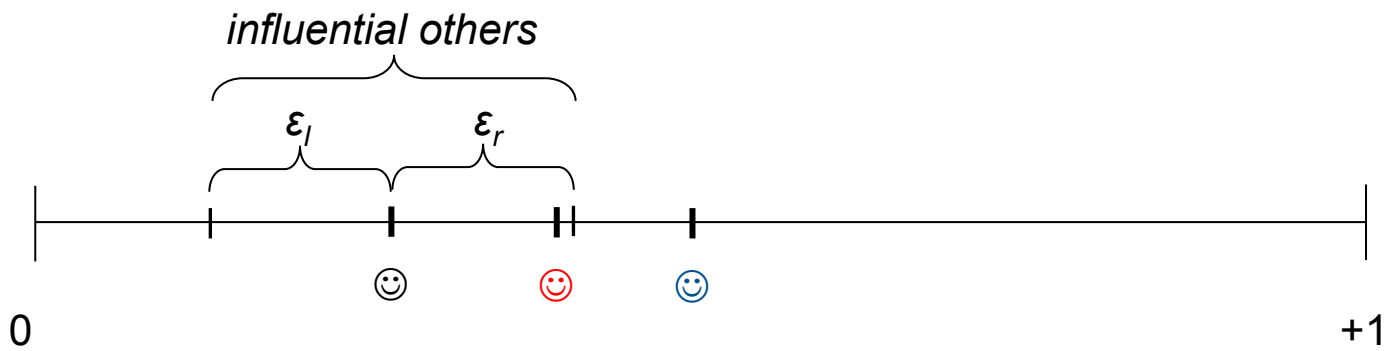
You have 3 minutes.

Bounded-Confidence models

- The Bounded Confidence Model has been developed by Hegselmann and Krause. However, there is also a second group of researchers around Guillaume Deffuant that developed a very similar model.
- **Basic assumptions**
  - Continuous opinions
  - Agents can in principle be influenced by all others (full network)
  - Influence weights are <u>not</u> linear and are <u>not</u> stable
    - All agents within a certain confidence interval ε_i have the same influence on i
    - All agents outside this confidence interval have **no** influence on i

Ulrich Krause

Rainer Hegselmann

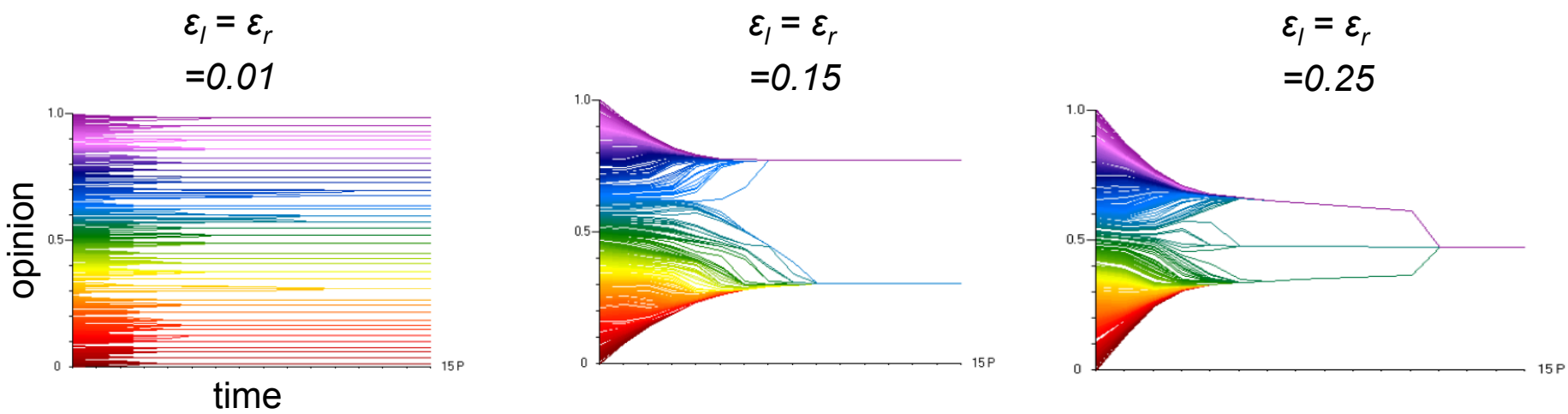


- The assumption of a bounded confidence is very similar to the assumption of homophily that Axelrod included
- Many assumptions concerning ε_l and ε_r are possible, e.g.
  - ε_l and ε_r are the same for all agents (uniform level of confidence)
  - $\varepsilon_l = \varepsilon_r$ (symmetric confidence)
  - ε_l and ε_r depend on the opinion (opinion dependent confidence)
- Influence is implemented as a weighted averaging process (weights $w_{ij,t}$ are zero or one, depending on similarity between *i* and *j*)

$$\Delta o_{i,t} = \frac{\sum_{j=1}^{N}(o_{j,t} - o_{i,t})w_{ij,t}}{\sum_{j=1}^{N} w_{ij,t}}$$

Symmetric confidence ($\varepsilon_l = \varepsilon_r$)

- Hegselman and Krause conducted computer simulations
  - 625 agents
  - Uniform distribution of opinions at the outset
  - Simultaneous updating
- Three typical simulation runs:



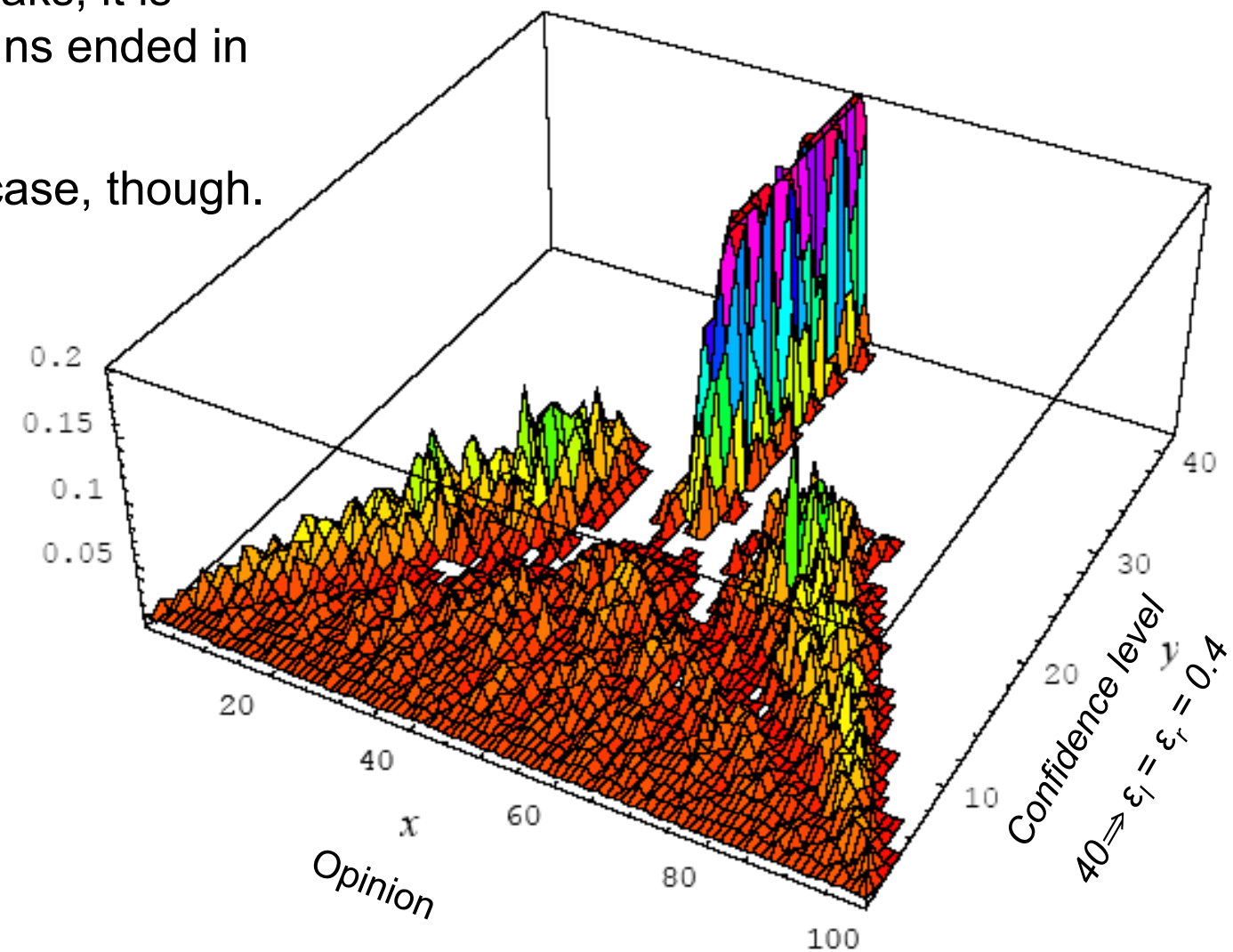
Line color depicts initial opinion of agents

- Results of simulation experiments (50 runs per BC-condition)

Note that this figure is somewhat misleading (also when the figure shows e.g. two peaks, it is possible that all runs ended in consensus.

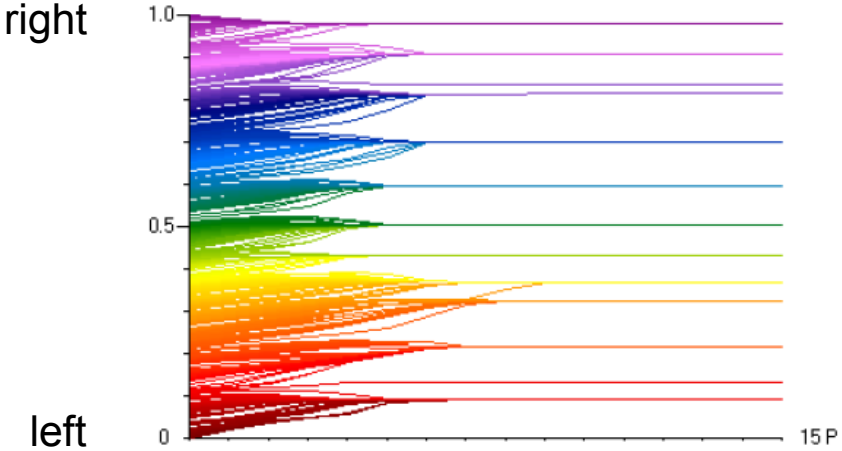
This was not the case, though.

Average relative frequency of opinion

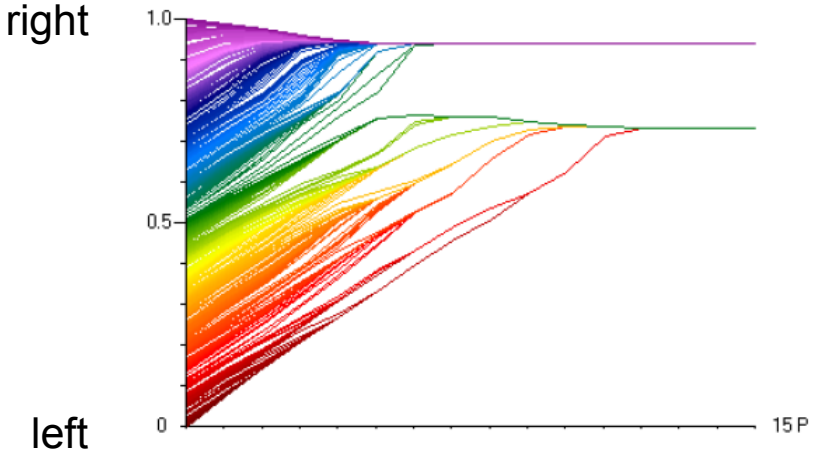


Asymmetric confidence ($\varepsilon_l < \varepsilon_r$)

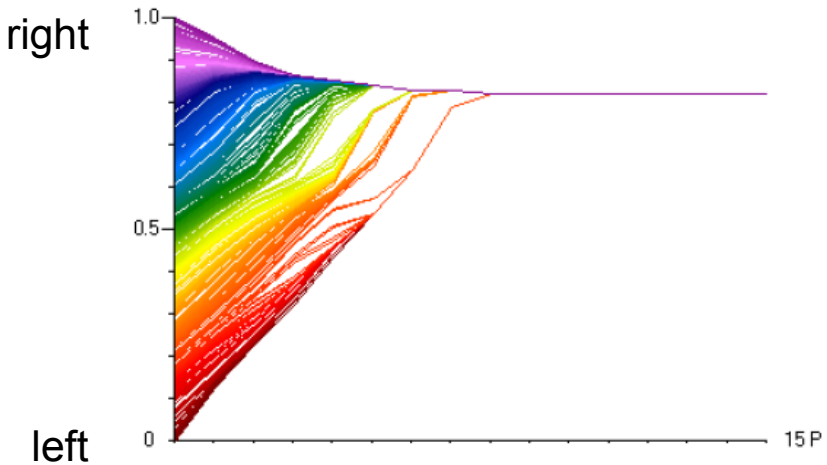
$\varepsilon_l = 0.02$ $\varepsilon_r = 0.04$



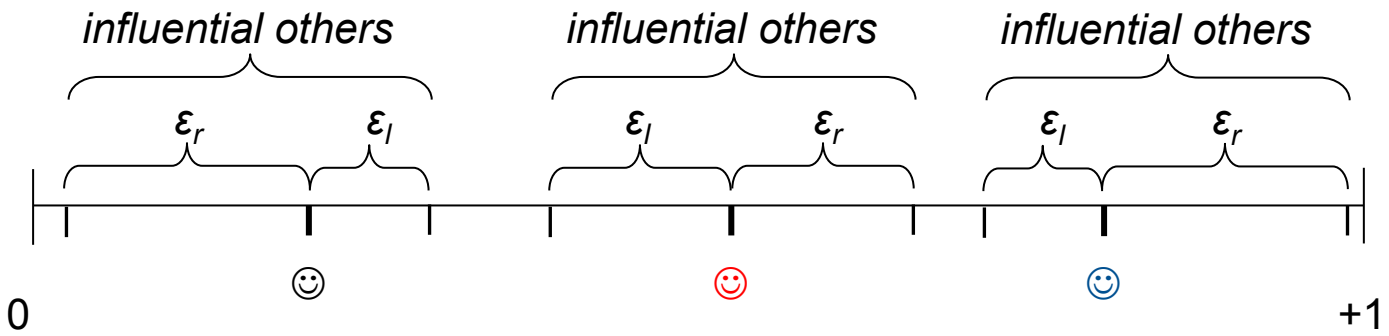
$\varepsilon_l = 0.03$ $\varepsilon_r = 0.15$



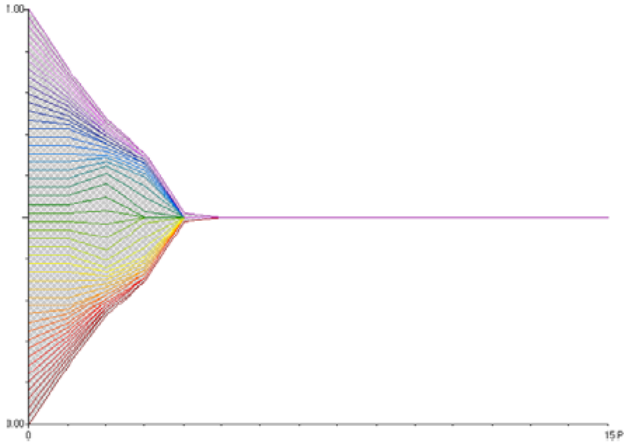
$\varepsilon_l = 0.10$ $\varepsilon_r = 0.25$



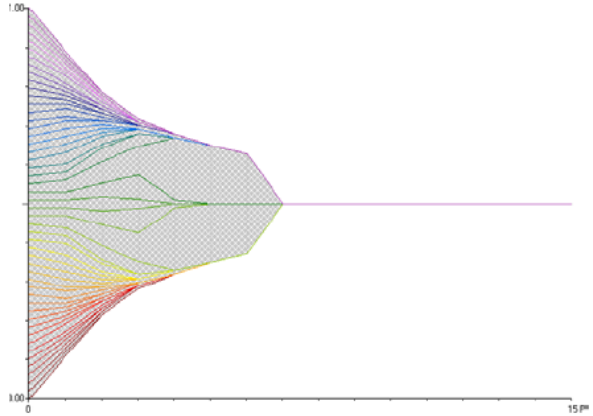
Opinion dependent Asymmetry



m=0



m=0.25

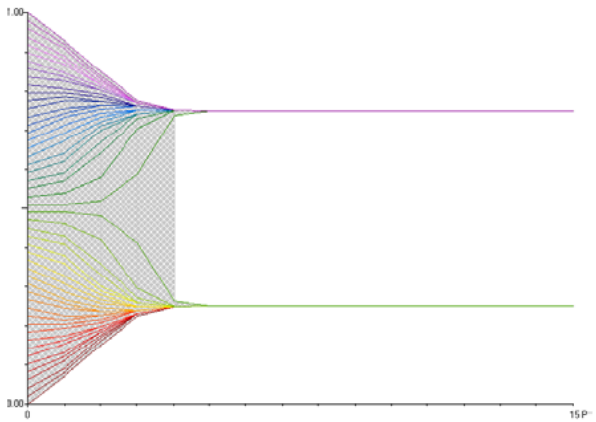


$\varepsilon_l + \varepsilon_r = 0.6$

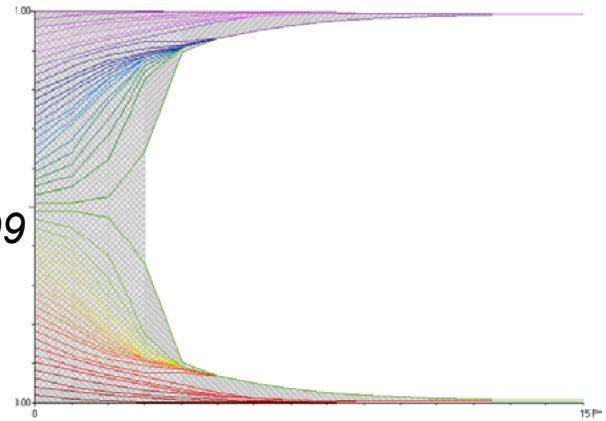
m=0 - no bias

As m increases, bias becomes stronger

m=0.5

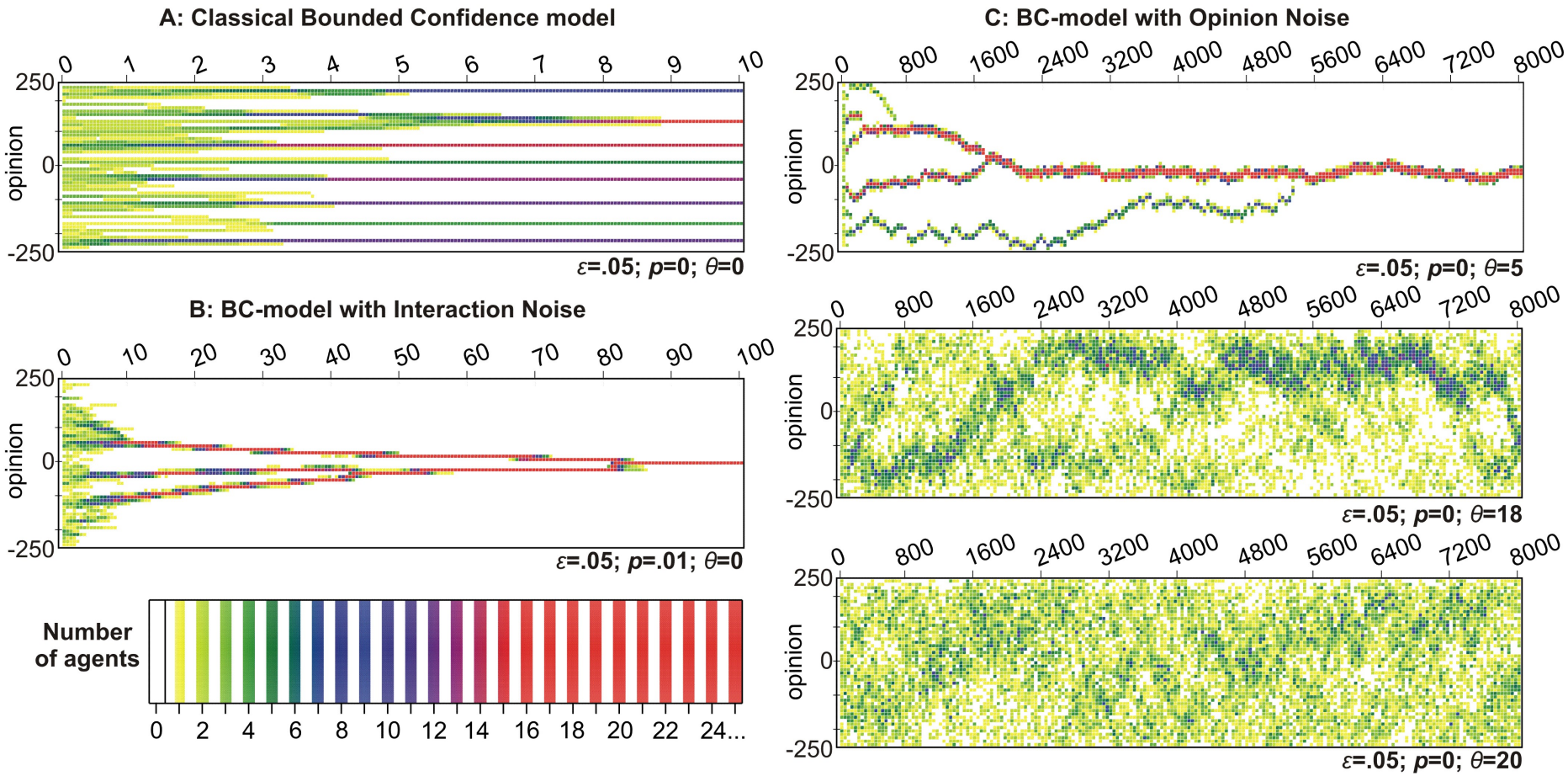


m=0.99



But there is a big problem ..

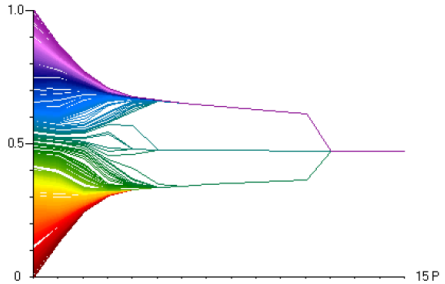
- The predictions of the BC-models are not robust to noise



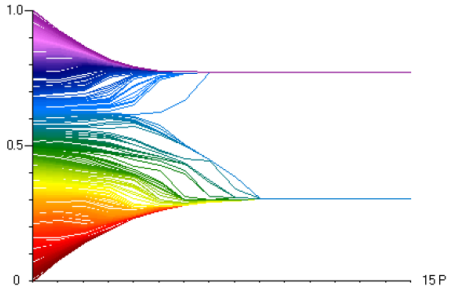
- Interaction noise: there is a probability of *p* that *j* influences *i* even though they are too dissimilar
- Opinion noise: After the update, a white noise term with average zero and std. dev. θ is added to the opinion

Summary and Discussion of BC-Models

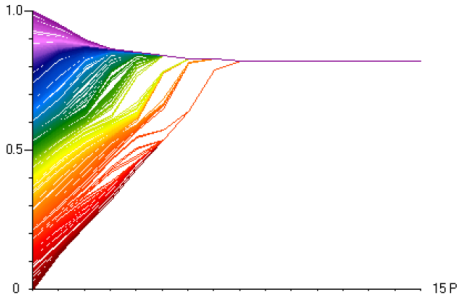
- BC-model can generate consensus
  - Ok, this is easy



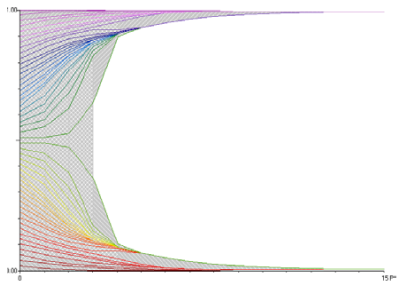
- BC-model can generate stable clustering
  - However, opinions converge when we add noise
  - And it does not work when population starts with consensus. The model can not generate diversity.



- BC-model can generate extremization
  - However, you need to assume a BC-bias (asymmetric confidence)



- BC-model can generate polarization
  - However, the poles are not really reached
  - and you need extremists who are less open to influence (opinion dependent asym.)
  - Where do the extremists come from? BC-model fails to generate extremists but relies on their existence to explain diversity.



Models of negative influence

- 4 core mechanisms
  - Homophily (liking of similar others)
  - Heterophobia (disliking of dissimilar others)
  - Social influence (tendency to become more similar to those I like)

  - Rejection aka. distancing or negative influence (tendency to become more dissimilar to those I dislike)

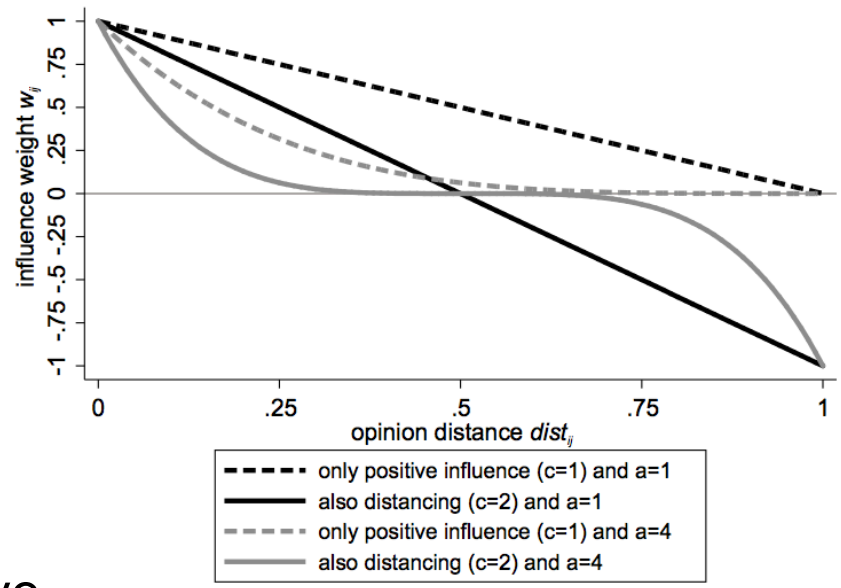
- Formally, opinion $o_{i,t}$ of agent i at time point t is calculated in the same way as in the classical models and the BC-model:

$$\Delta o_{i,t} = \frac{\sum_{j=1}^{N} (o_{j,t} - o_{i,t}) w_{ij,t}}{\sum_{j=1}^{N} w_{ij,t}}$$

- This is just weighed averaging (like in the BC-model), but weights can be negative:

$$w_{ij} = (1 - c \cdot dist_{ij,t})^a \quad if \quad dist_{ij,t} \leq \frac{1}{c}$$

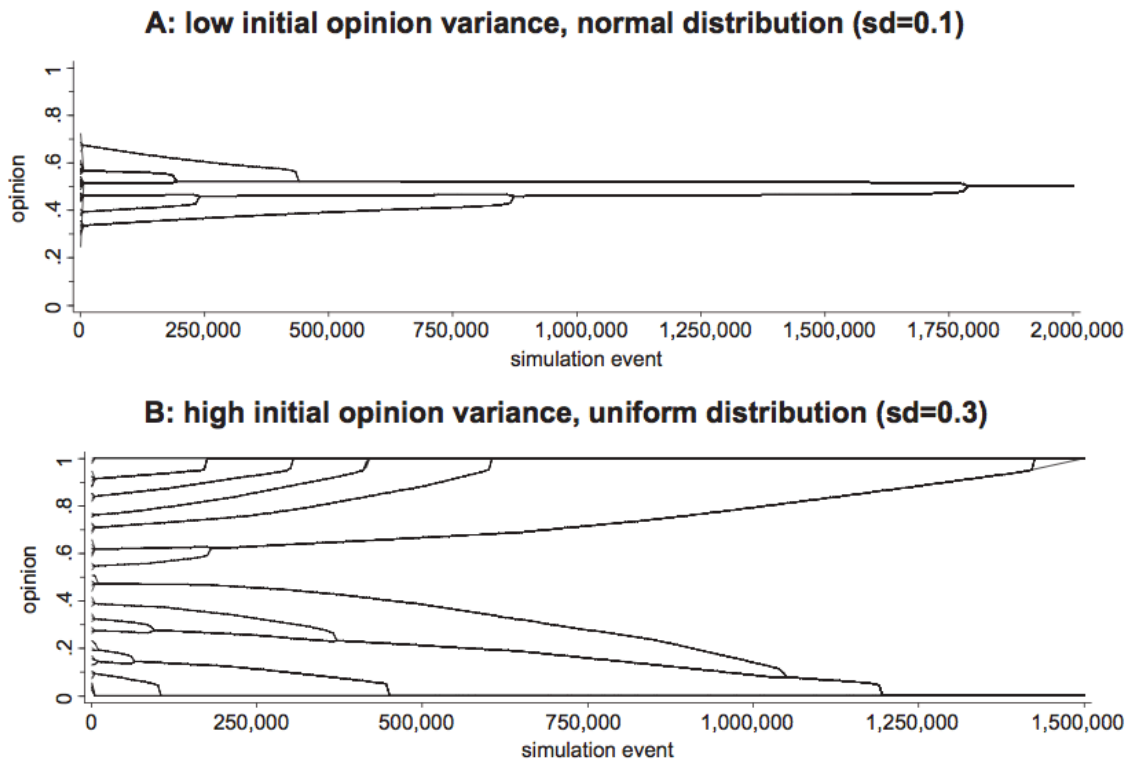
$$w_{ij} = -1(c \cdot dist_{ij,t} - 1)^a \quad if \quad dist_{ij,t} > \frac{1}{c}$$



- 1/c is the critical distance at which influence shifts from positive to negative

Model predictions

- There are three possible outcomes:
  - consensus
  - opinion polarization (two maximally different clusters)
  - multiplex equilibria (two opposing groups of extremists and moderates who do not move because they are pulled in both directions)
- Outcome depends on initial opinion variance



Summary and Discussion of the negative-influence approach

- The model can generate polarization (at the extremes)
  - Predictions are quite robust to inclusion of opinion noise
  - Extremists at the beginning are not needed

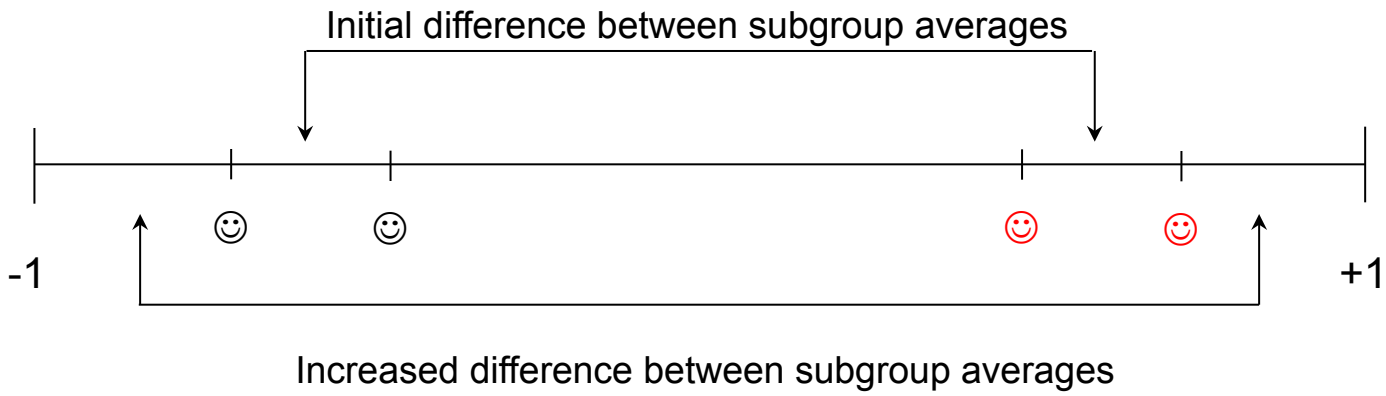
- Problems:
  - Mixed empirical confirmation for rejection mechanism
  - Model fails to generate extremization (all agents move towards one extreme)
  - Can not generate polarization out of consensus

The persuasion model

- Averaging is plausible when agents with different opinions influence each other. It implies, however, that there are no opinion changes when agents with similar opinions interact
- Empirical research on the outcomes of group discussions support the notion that our opinions can be intensified when we interact with someone who holds similar views
- Persuasive argument theory offers an explanation: Individuals communicate arguments during interaction. If you learn a new argument that supports your initial opinion, they you become more convinced/ extreme.

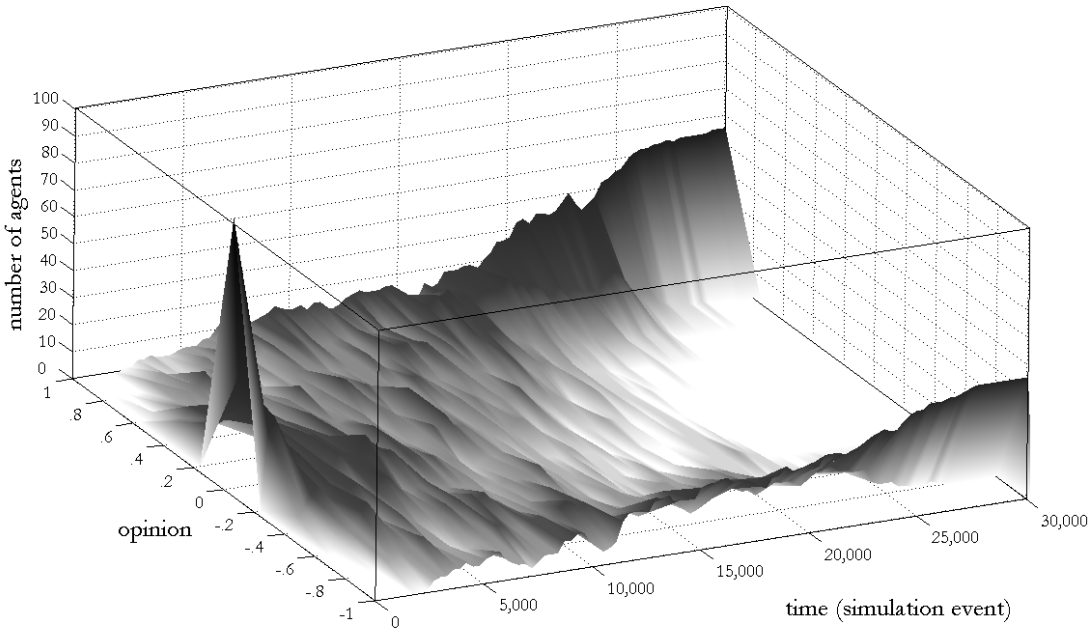
Core assumptions

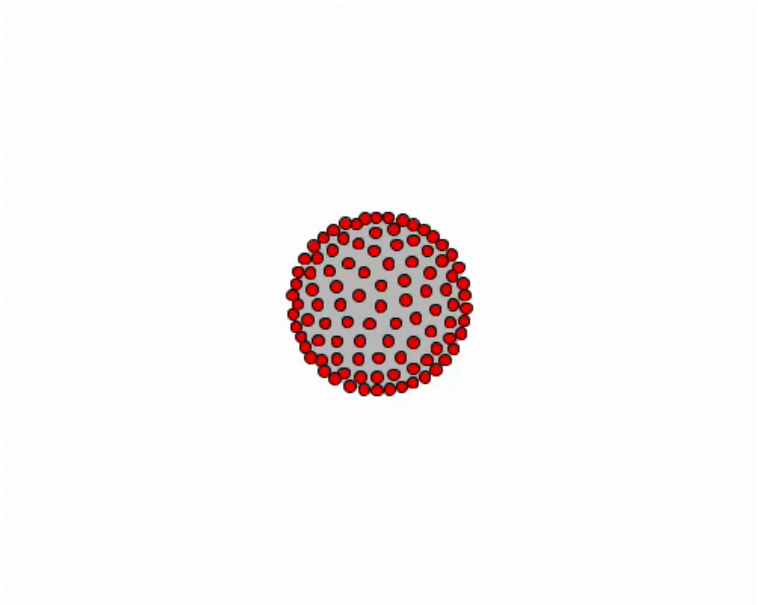
- Opinions are function of the arguments that agents consider relevant
- Arguments are either pro (more positive opinion) or con (more negative opinion)
- Influence is not modeled as averaging but is based on the communication of arguments.
- When two agents interact, one adopts an argument that the other considers relevant (and drops a dated argument)
- In combination with **homophily** (implemented the same way as in Axelrod's model), this can lead to opinion polarization



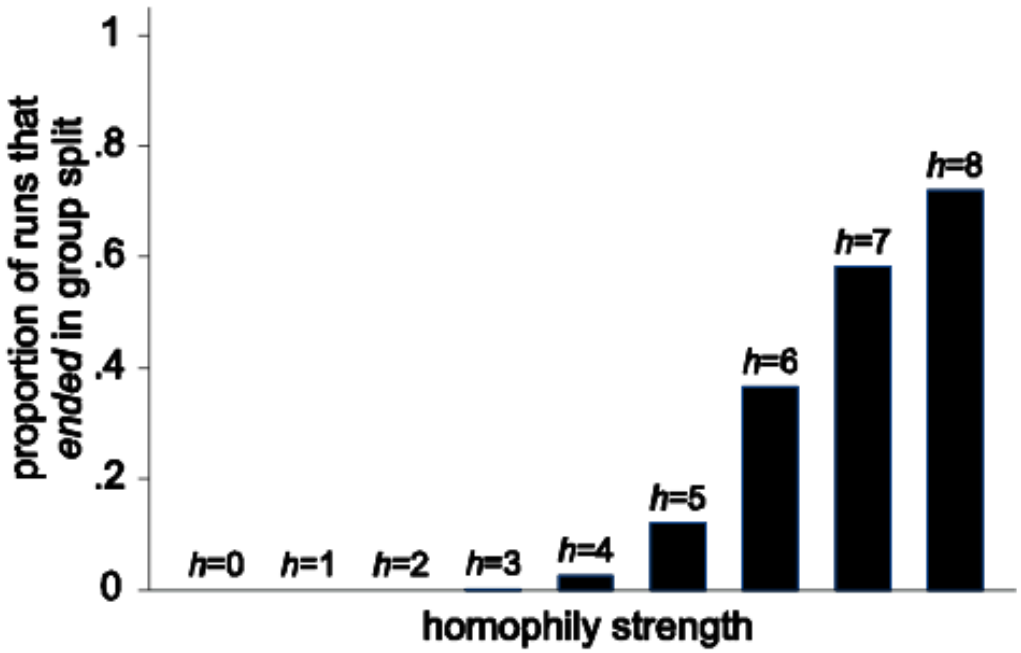
Typical run

- At the outset, all 100 agent hold same opinion but base opinions on different sets of 5 pro and 5 con arguments
- Eventually, there are two maximally dissimilar and stable subgroups





- Strong homophily is a necessary condition of opinion polarization



$$p_{j,t} = \frac{\left(sim_{i^*,j,t}\right)^h}{\sum_{p=1, p \neq i^*}^{N-1} \left(sim_{i^*,p,t}\right)^h}$$

$$sim_{i^*,j,t} = \frac{1}{2}\left(2 - \left|o_{i^*,t} - o_{j,t}\right|\right)$$

$p_{j,t}$ is the probability that *i* selects *j* as interaction partner at time point *t*

Summary and Discussion of the persuasion approach

- The model can generate polarization (at the extremes)
  - Strikingly, there is no negative influence
  - Mechanisms (homophily and persuasion) are well supported by empirical research
  - No initial opinion diversity needed

- Problems:
  - Existing models are not robust to noise
  - Models rely on assumptions about the forgetting of arguments (otherwise agents consider relevant all arguments in the end) and there is little research on these cognitive processes

Can we prevent opinion polarization?

Handle 1: Demographic attributes

- Individuals select interaction partners not only based on opinion similarity but also based on demographic similarity

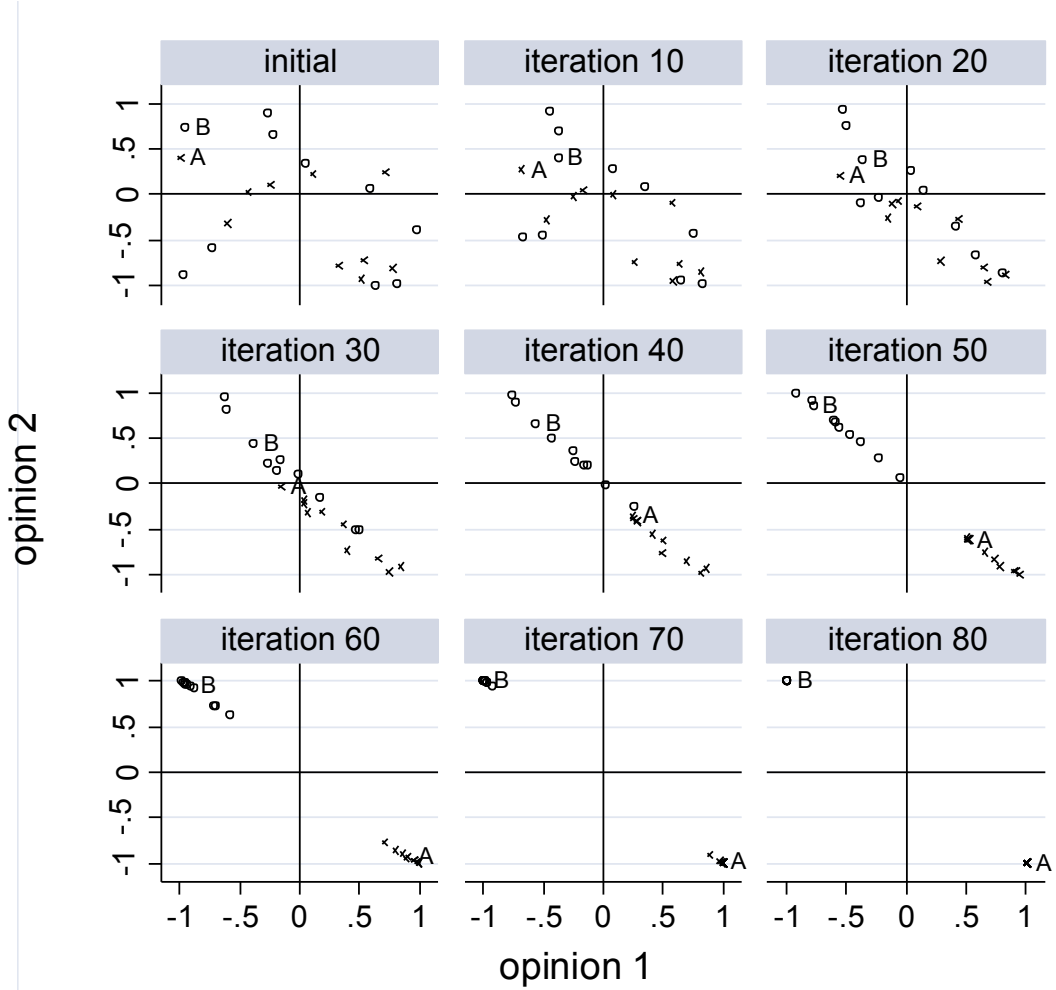
Discuss with your neighbor

Will there be more or less opinion polarization when individuals differ also on demographic dimensions?

You have 3 minutes.

Handle 1: Demographic attributes

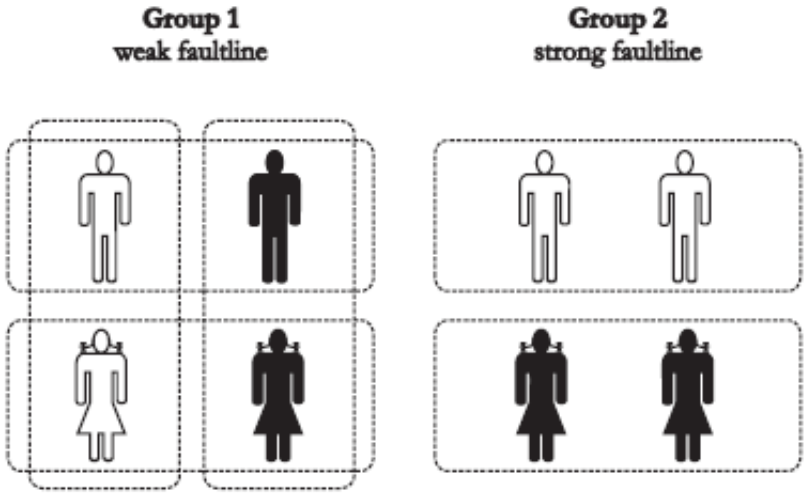
- Individuals select interaction partners not only based on opinion similarity but also based on demographic similarity



Model with negative influence

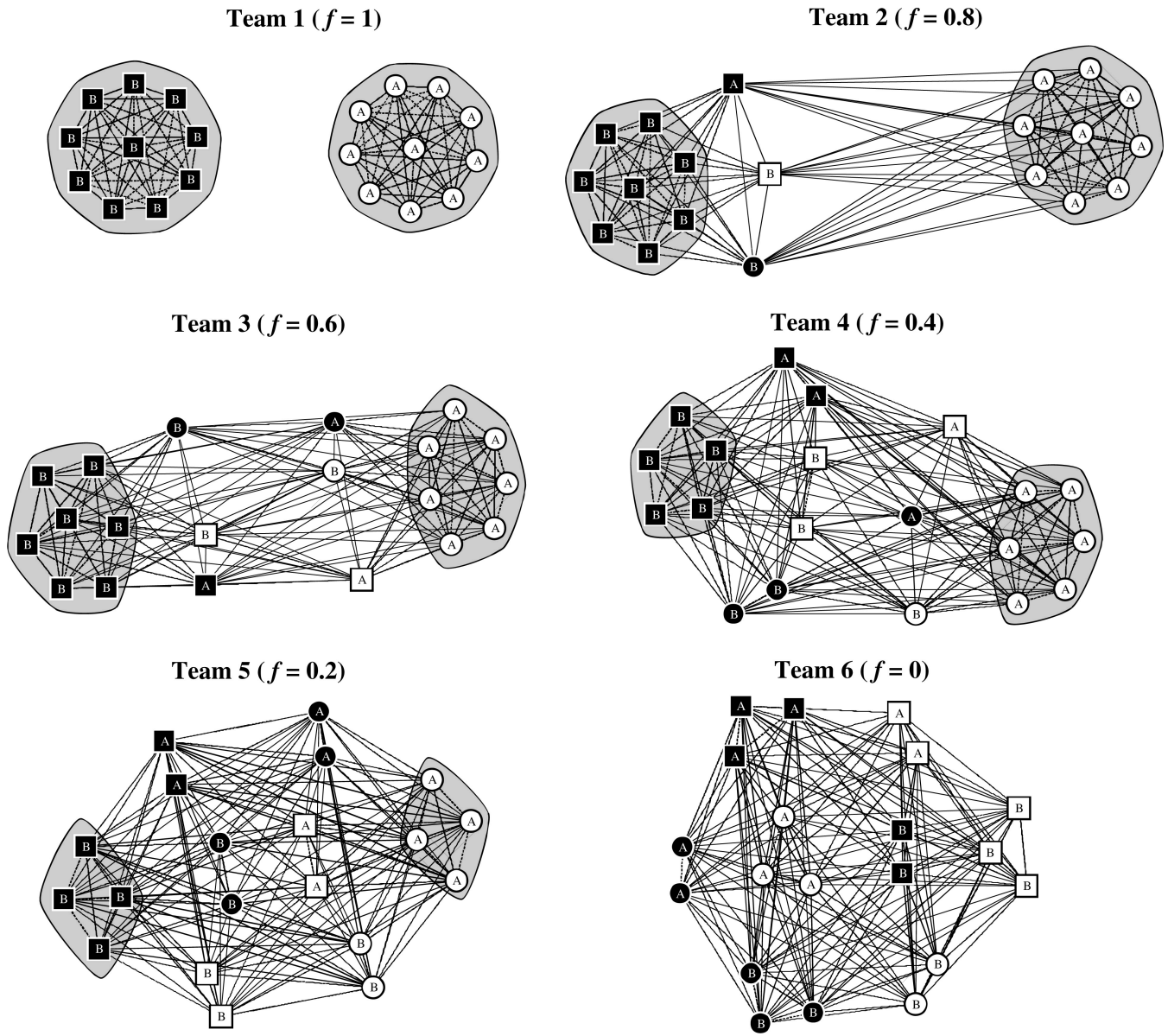
- Two opinion dimensions
- graph assumes opinion scale that varies from -1 to +1
- Demographic attributes d_i are fixed but have impact on influence weights
- Circles: d_i = -1
- Crosses: d_i = 1

- Demographic attributes appear to introduce new dividing lines, which might lead to negative influence or (if homophily is strong) subgroups that hardly communicate arguments
- However, when multiple demographic attributes are relevant, the effect on opinion polarization depends on the degree to which attributes are correlated
- Lau and Murnighan introduced the concept of “faultline strength”.



The two groups have the same diversity (50:50) but differ in faultline strength

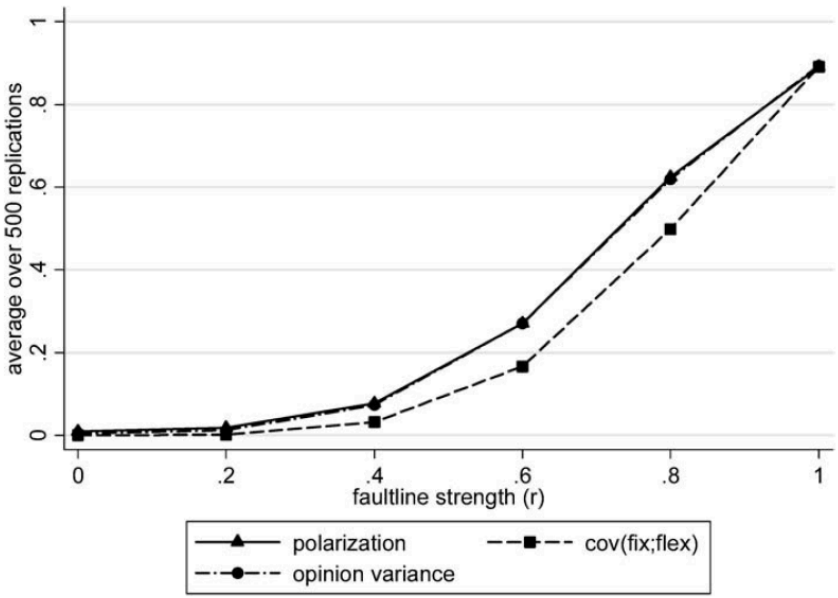
J. Keith Murnighan



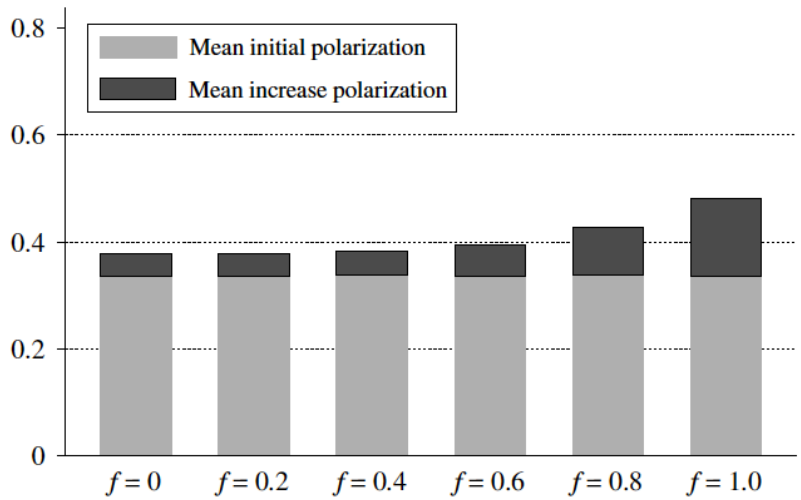
- Groups of 20 agents. Each agent is described on three dimensions
- *f* = Pearson correlation between demographic variables

- The negative influence models and the persuasion models predict that opinion polarization is more likely when faultlines are strong

Negative-influence model



Persuasion model



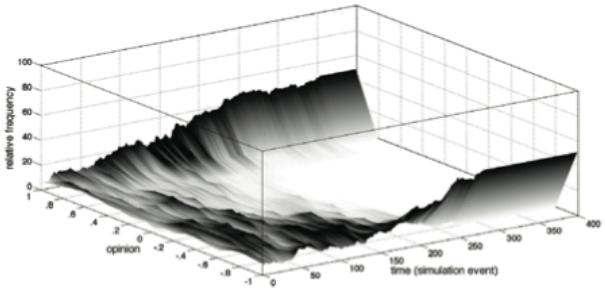
- Thus, in order to prevent opinion polarization in groups and organizations, we may want to avoid group compositions with strong faultlines
- This may be of importance for managers of work teams, as demographic diversity implies a great potential for high performance and also weak-fautline teams can be very diverse.

Handle 2: Homophily

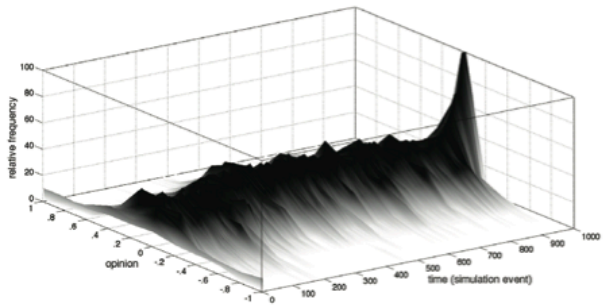
- Models that assume negative influence (aka rejection) as well as the persuasion models imply effects of homophily. The direction of the effect, however, differs fundamentally.

Persuasion Model

A: Homophily

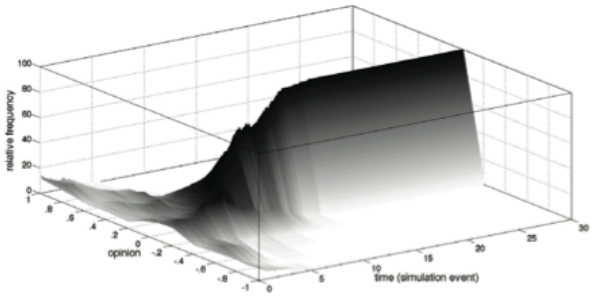


B: No homophily

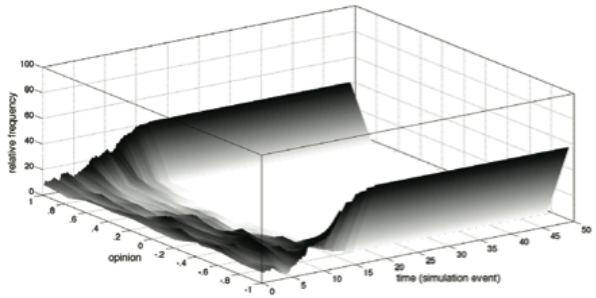


Rejection Model

C: Homophily



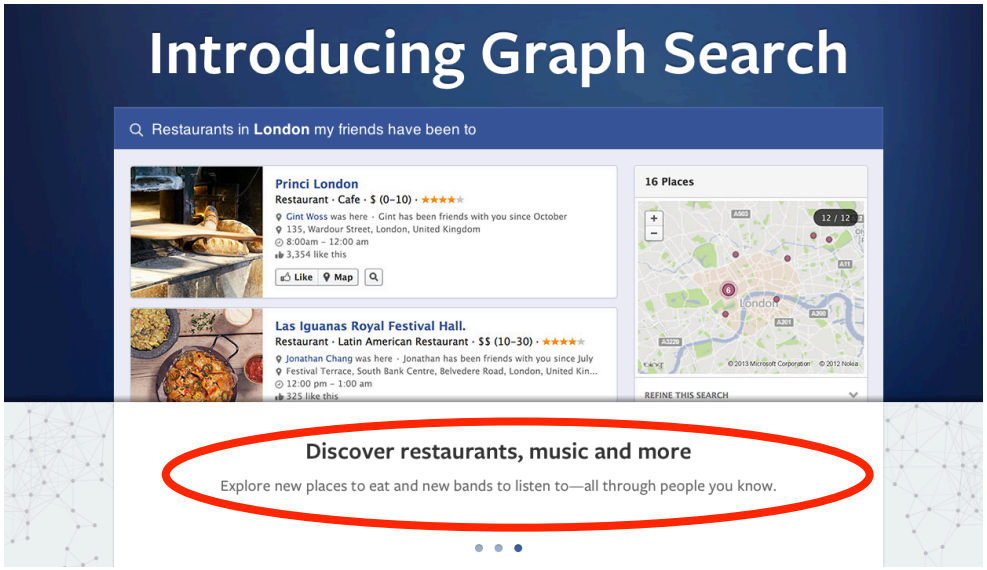
D: No homophily



Can we manipulate the strength of homophily in a population?

- This is a crucial question. If this is not possible, then the advice (vary homophily in order to decrease polarization) has little “practical content”

- It turns out that homophily may be intensified by new search-engine algorithms and linking algorithms on social-network sites



Google Search for Egypt

Scott: Egyptian Protests

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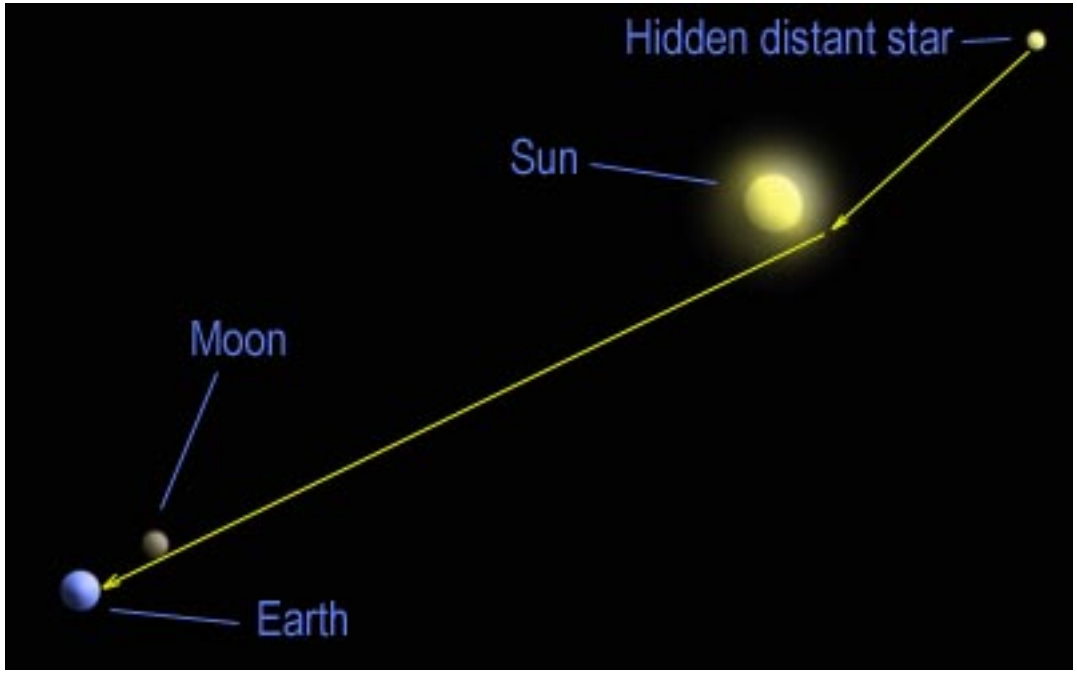

Aims of this lecture

- Understand “Abelson’s puzzle” of opinion polarization
- Understand classical models of social influence
- Understand existing approaches to opinion polarization and clustering of opinions
- Discuss ways to prevent opinion polarization

Literature

Classical models of social influence

- Abelson, Robert P. 1964. "Mathematical Models of the Distribution of Attitudes under Controversy." Pp. 142-160 in *Contributions to Mathematical Psychology*, edited by N. Frederiksen and H. Gulliksen. New York: Rinehart Winston.
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Bounded-Confidence and Noise

- Hegselmann, Rainer and Ulrich Krause. 2002. "Opinion Dynamics and Bounded Confidence Models, Analysis, and Simulation." *Journal of Artificial Societies and Social Simulation* 5 (3).
- Mäs, Michael, Andreas Flache, and Dirk Helbing. 2010. "Individualization as Driving Force of Clustering Phenomena in Humans." *PLoS Computational Biology* 6 (10):e1000959.

Negative influence plus demographic faultlines

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Persuasion plus demographic faultlines

- Mäs, Michael, A. Flache, Károly Takács, and Karen Jehn. 2013. "In the Short Term We Divide, in the Long Term We Unite. Crisscrossing Work Team Members and the Effects of Faultlines on Intergroup Polarization." *Organization Science*.