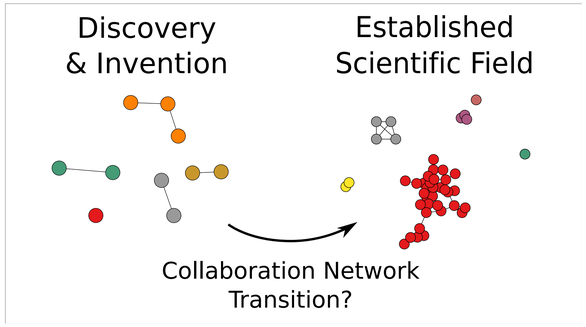
Measuring Topological Transitions in Scientific Collaboration Networks Using Topic Modeling for Subfield Detection

Daniel T. Citron[1], Samuel F. Way[2], Laurence Brandenberger[3]

[1] *Laboratory of Atomic and Solid State Physics, Cornell University* [2] *Department of Computer Science, University of Colorado* [3] *Institute of Political Science, University of Bern & Eawag*

Scientific Collaborations

How do scientific fields develop? How does a network of researchers coalesce around a scientific topic? How does a network of scientific collaborators assemble over time? **Do we observe social restructuring among researchers as their field develops?**



A global topological transition: Previous studies have observed that fields begin as disparate, disconnected groups. Over time, enough collaborators join the field such that it forms a single, densely-connected giant component.

Topic modeling: Previous studies were restricted to a small survey of fields due to reliance on human experts to curate their data sets. Our contribution is to bypass this limitation using document classifying algorithms on a large scientific corpus.

- Access to document corpora enables large-scale analyses
- Topic modeling enables rapid classification of increased number of subfields

ArXiv Data Set

The arXiv - a freely available online repository of scientific preprints, mostly related to Physics, Computer Science, and Mathematics. We focus on condensed matter physics ("**cond-mat**") articles:

- 189,000 articles total
- 680,000 unique authors
- Taken from April 1992 through June 2015
- Use titles, abstracts of articles, author names
- Month & year of submission encoded in arXiv ID

Contact: dtc65@cornell.edu

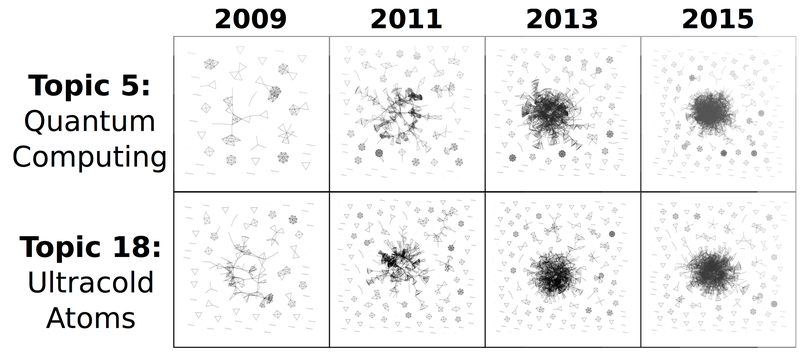
Topic Modeling

We implement **Latent Dirichlet Allocation** to classify the article titles and abstracts from **cond-mat**. LDA classifies documents by characterizing thematic content underlying the textual content. Given word co-occurrence in the document set, LDA returns probability distributions of words across topics and topics across documents. We use N**= 50 topics** and find that 45/50 are readily interpretable as scientific subfields.

Example: Interpreting Topic 5

- Keywords: *quantum state qubit coupling measurement qubits entanglement cavity coupled decoherence*
- Example paper title: "Controllable coupling between flux qubits"
- Interpretation: **Quantum Computing**

Network Assembly



We find groups of articles strongly associated ($p > 0.6$) with each topic, construct the corresponding co-authorship network, and observe how it changes over time. For topics that represent scientific subfields, we **consistently observe the formation of a dense giant cluster for 28/45 of the scientific subfields identified with LDA**.

Citations and Acknowledgements

1. L. M. A. Bettencourt, *et al.* Scientific discovery and topological transitions in collaboration networks. *Journal of Informetrics* (2009).
2. D. M. Blei, *et al.* Latent dirichlet allocation. *The Journal of Machine Learning Research* (2003).

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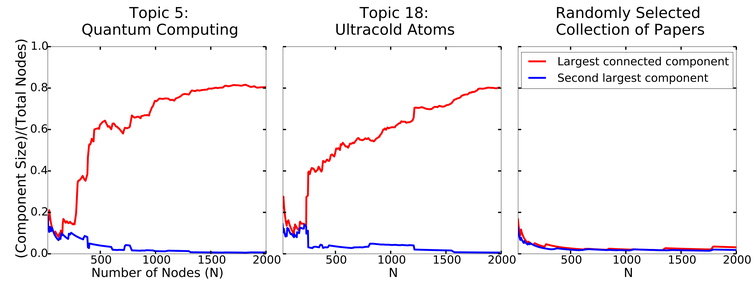
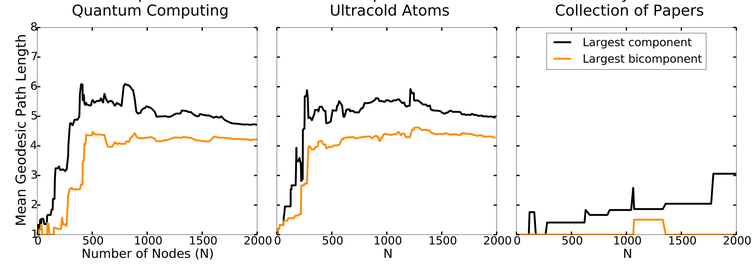
Network Assembly Measurements

Giant Component Formation



- Largest connected component dominates network
- **Global topological transition**

Mean Geodesic Paths



- Initial growth, rapid consolidation
- Establishment of **long ties**
- Distant research groups overlap at transition

Discussion

For many topics in condensed matter physics, we observe the same pattern: a **global topological transition** to a densely-connected community of collaborators following a period of scatterred initial growth. The formation of the giant cluster represents **social reorganization** as a subfield develops over time.

Future work:

- Microscopic model for network assembly to explain quantitative features, test hypotheses of contagion and cooperation
- Homophily - can we model how an author's past research activities influence future collaborations?