Dynamic Poisson Factorization

Laurent Charlin

Joint work with: Rajesh Ranganath, James McInerney, David M. Blei
McGill & Columbia University

Presented at RecSys 2015

Cornell University Library

arXiv.org > cs > cs.LG

Learning

Authors and titles for recent submissions

- Mon, 25 Aug 2014
- Fri, 22 Aug 2014
- Thu, 21 Aug 2014
- Tue, 19 Aug 2014
- Mon, 18 Aug 2014

[total of 21 entries: **1-21**]
[showing up to 25 entries per page: fewer | more]

Mon, 25 Aug 2014

[1] **arXiv:1408.5389 [pdf, other]**

Computing Multi-Relational Sufficient Statistics for Large Databases
Zhensong Qian, Oliver Schulte, Yan Sun
Comments: 11pages, 8 figures, 8 tables, CIKM'14,November 3--7, 2014, Shanghai, China
Subjects: **Learning (cs.LG)**; Databases (cs.DB)

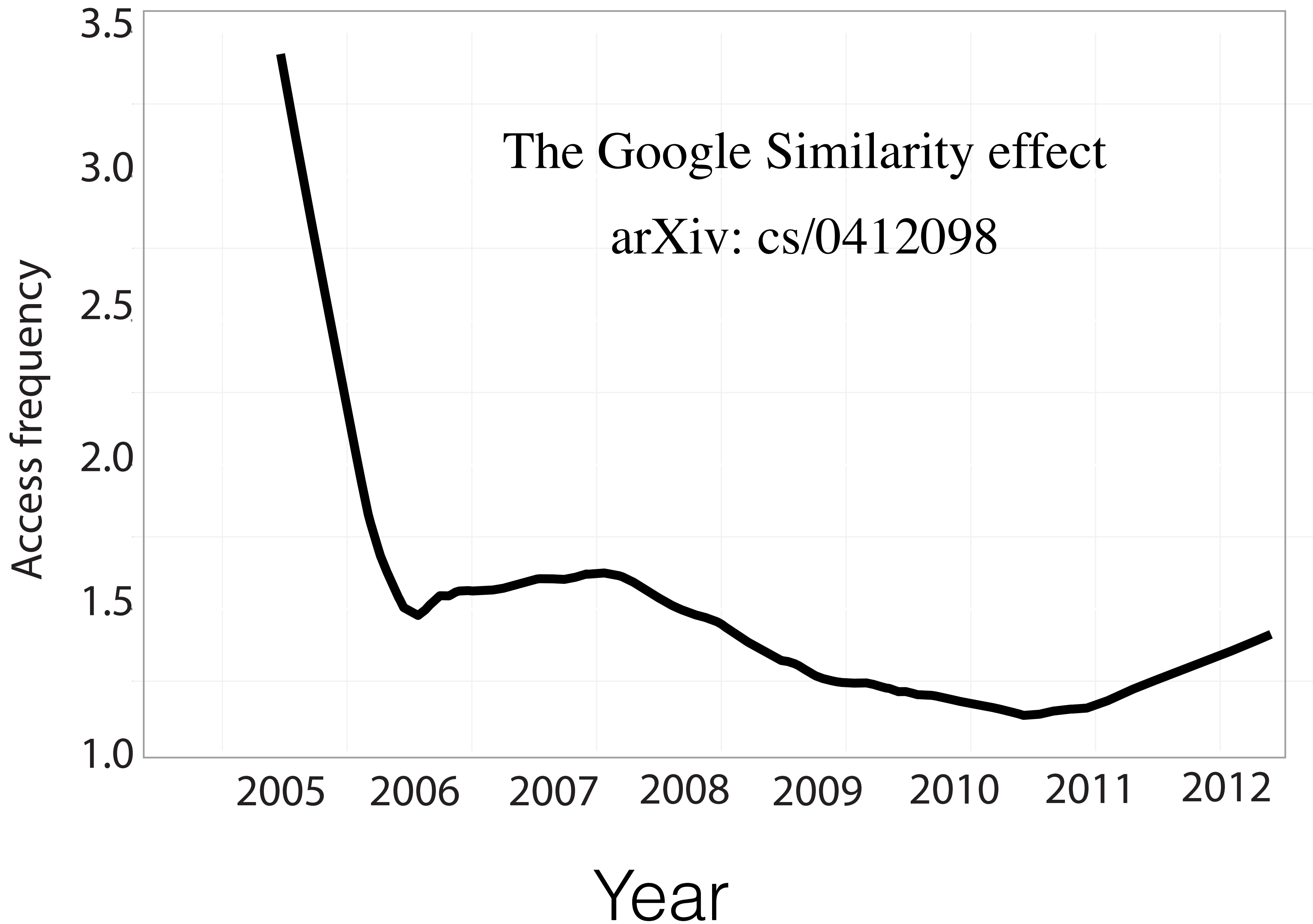
[2] **arXiv:1408.5246 [pdf]**

Improving the Interpretability of Support Vector Machines-based Fuzzy Rules
Duc-Hien Nguyen, Manh-Thanh Le
Comments: 8 pages, 2 figures
Subjects: **Learning (cs.LG)**; Artificial Intelligence (cs.AI)

[3] **arXiv:1408.5352 (cross-list from stat.ML) [pdf, other]**

Nonconvex Statistical Optimization: Minimax-Optimal Sparse PCA in Polynomial Time
Zhaoran Wang, Huanran Lu, Han Liu

Click Data for a paper

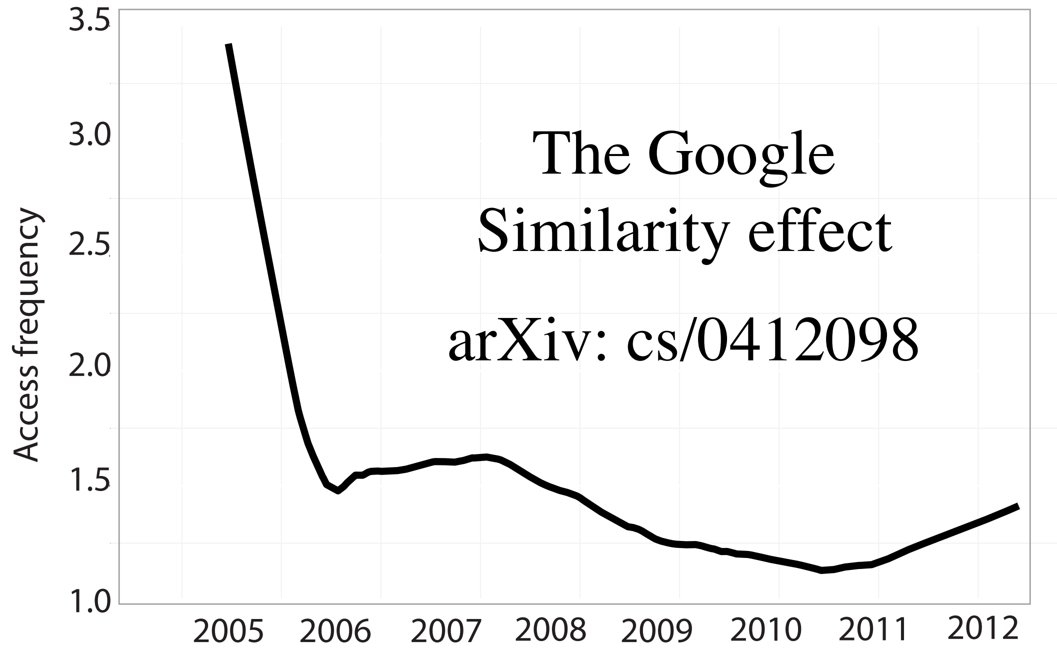


arXiv evolves over time

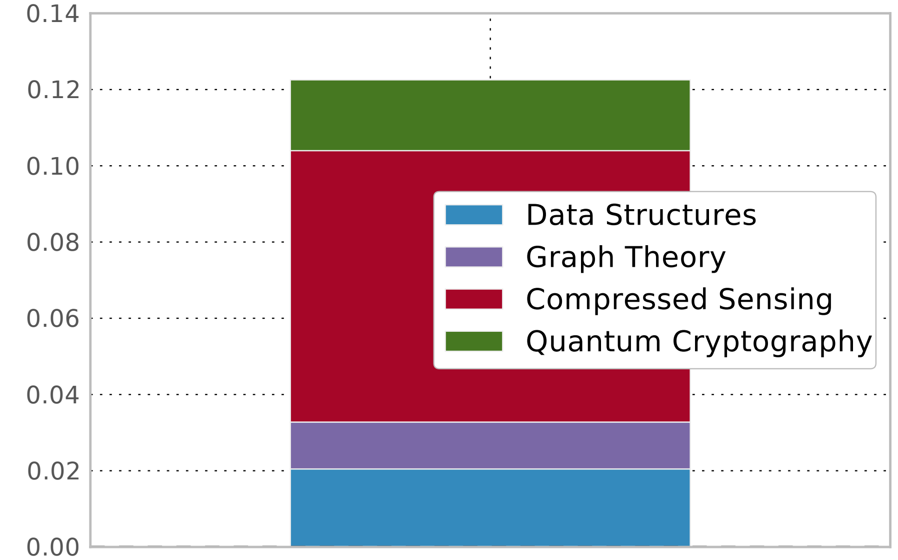
- Click data evolves over time
  - Popularity of papers change over time
  - Users’ interests change over time
- The same is also true of other datasets

Recommendations should evolve over time

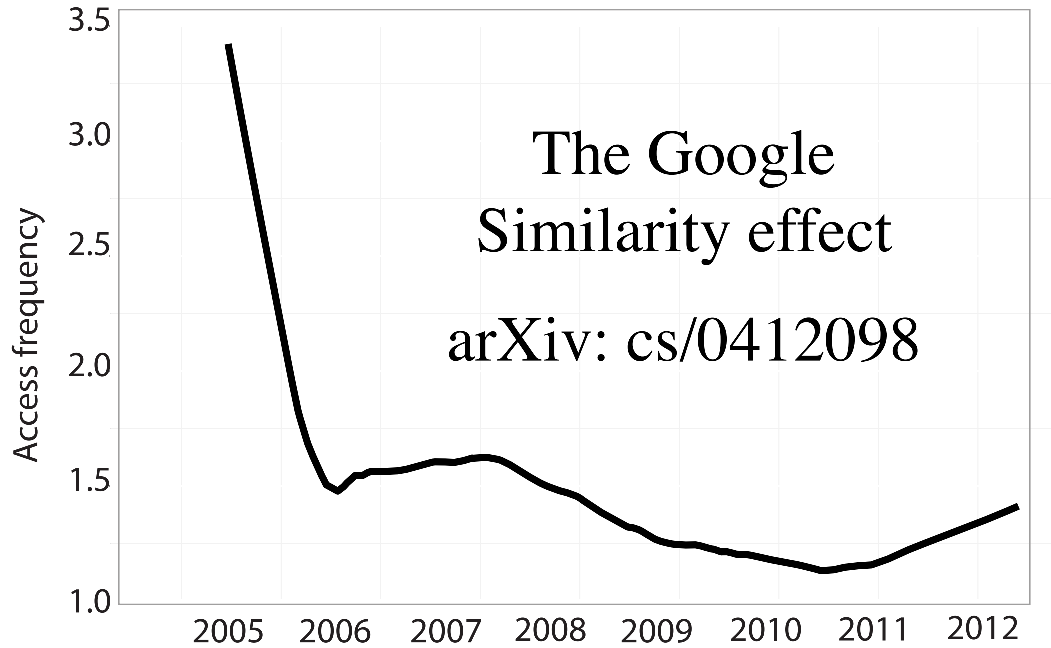
Raw Data



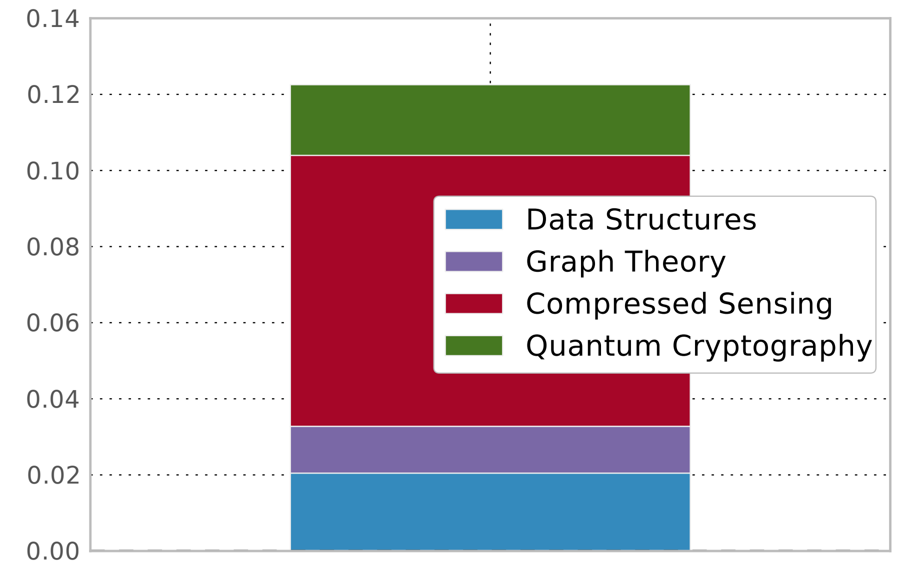
Modeled Data (e.g., Matrix Factorization)



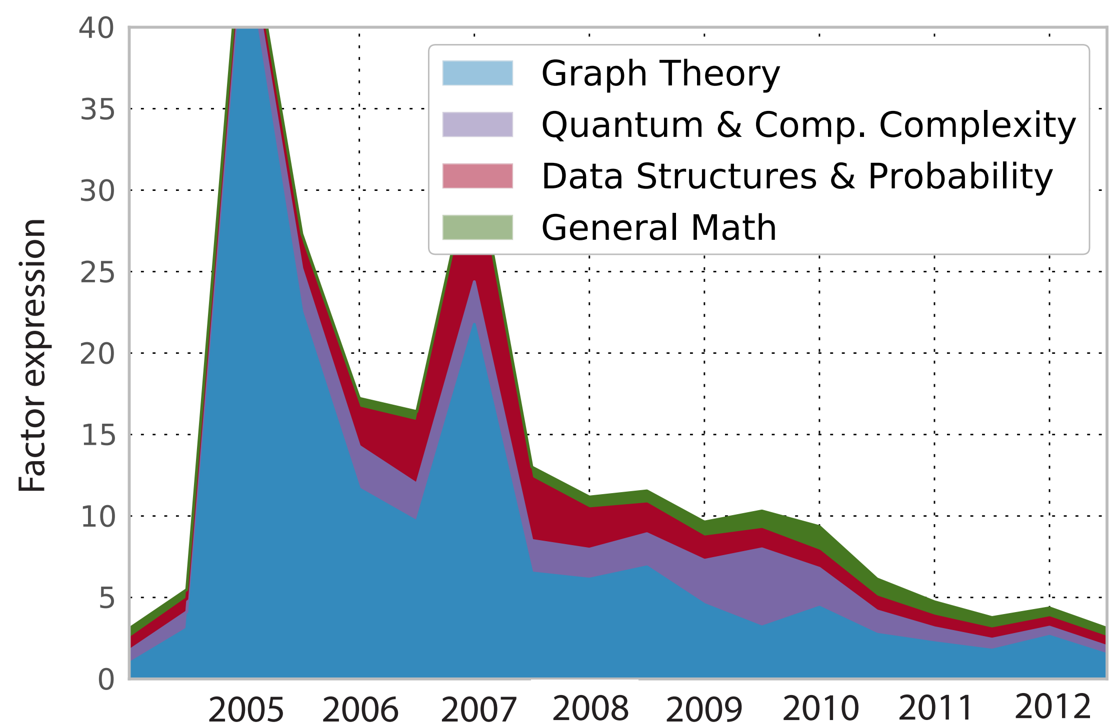
Raw Data



Modeled Data (e.g., Matrix Factorization)



Time-aware Modeled Data



Objectives

- Understand click data over time
  - Better predictions of future user interests
  - Explore how (large) datasets evolve over time
- Motivated by the arXiv
  - Study other datasets

Technical approach

- Dynamic model of user preferences
  - Poisson matrix factorization [Gopalan et al. UAI'15]
  - User and item latent factors evolve over time
  - Develop inference procedure
- Fit this model using data
- Explore fits

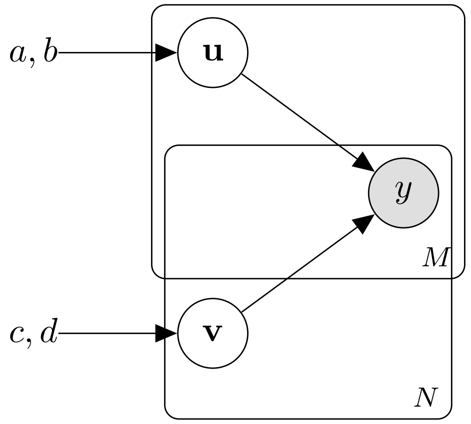
Data (e.g., clicks)

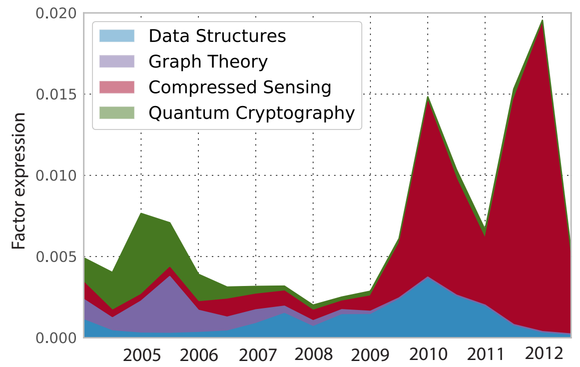
Recommendations

Generative Model

Learning & Inference

Exploration (latent factors)



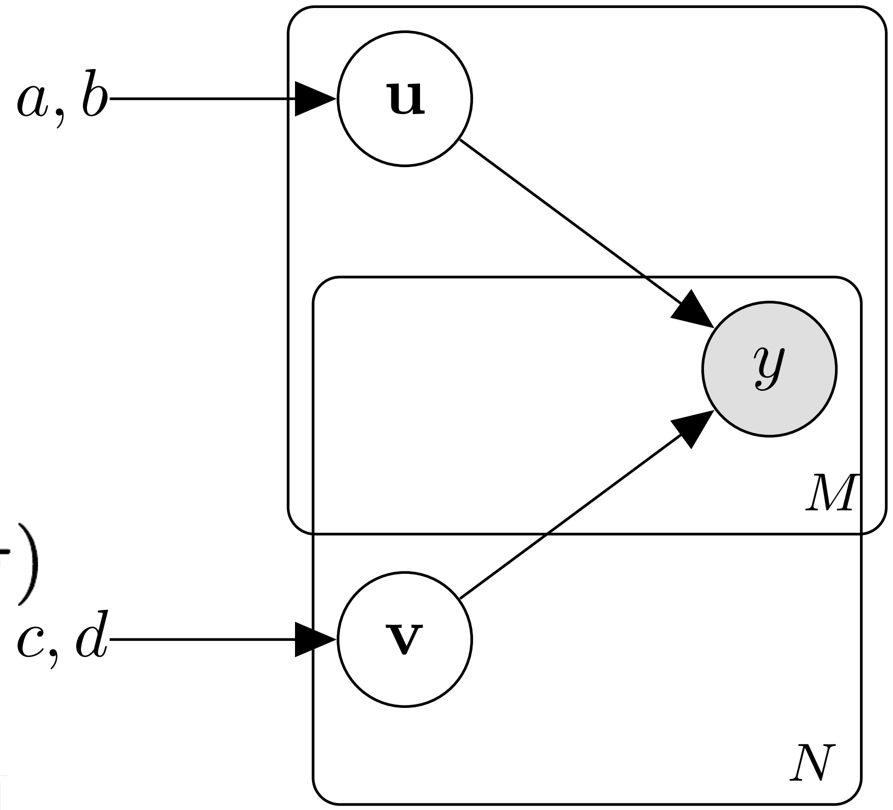


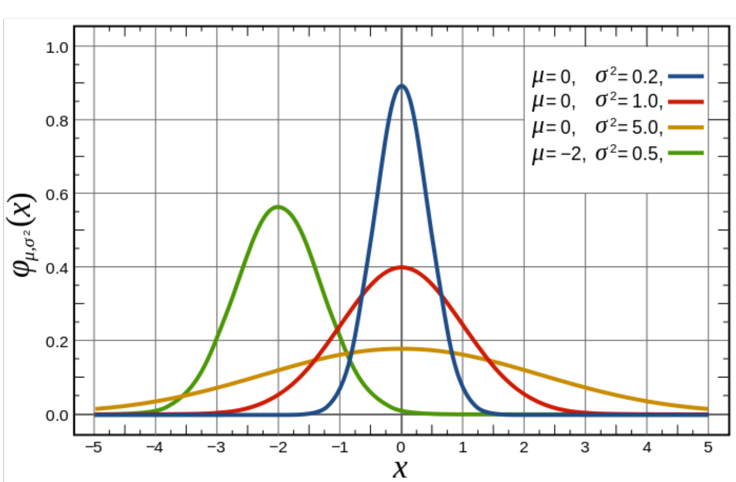
Background

Gaussian Matrix Factorization

[Salakhutdinov et al. '15]

$$\mathbf{u}_m \sim \mathcal{N}(a, b)$$
$$\mathbf{v}_n \sim \mathcal{N}(c, d)$$
$$y_{mn} \sim \mathcal{N}(u_m^\top v_n, \sigma)$$





[wikipedia]

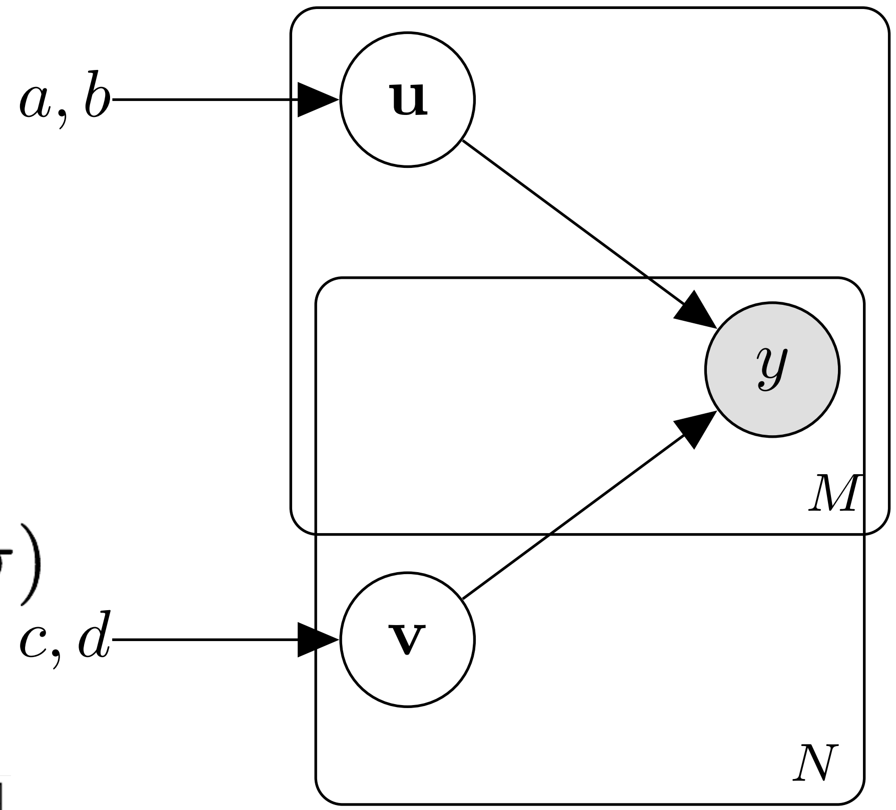
Gaussian Matrix Factorization

[Salakhutdinov et al. '15]

$$\mathbf{u}_m \sim \mathcal{N}(a, b)$$

$$\mathbf{v}_n \sim \mathcal{N}(c, d)$$

$$y_{mn} \sim \mathcal{N}(u_m^\top v_n, \sigma)$$



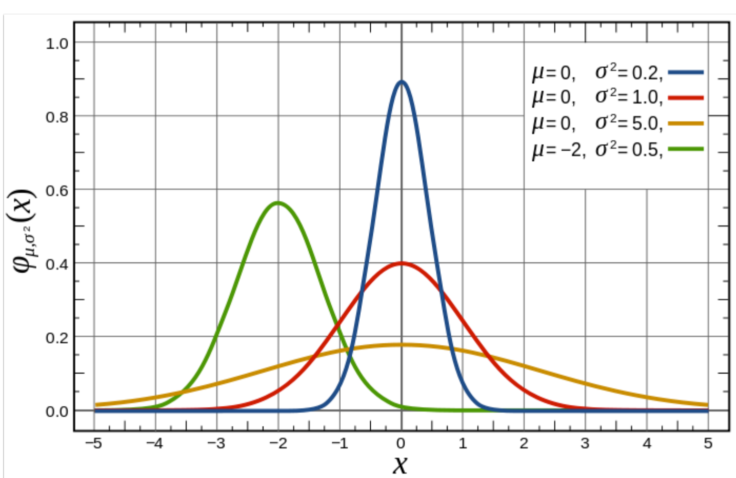
Poisson Matrix Factorization (PF)

[Gopalan et al. '15]

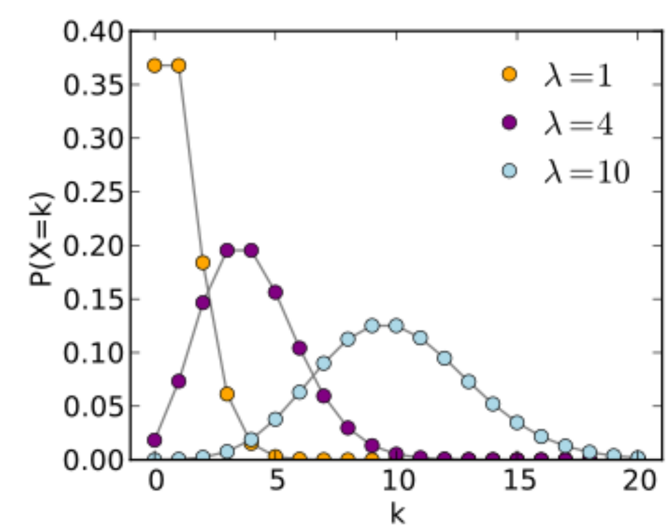
$$\mathbf{u}_m \sim \mathrm{Gamma}(a, b)$$

$$\mathbf{v}_n \sim \mathrm{Gamma}(c, d)$$

$$y_{mn} \sim \mathrm{Poisson}(u_m^\top v_n)$$



[wikipedia]

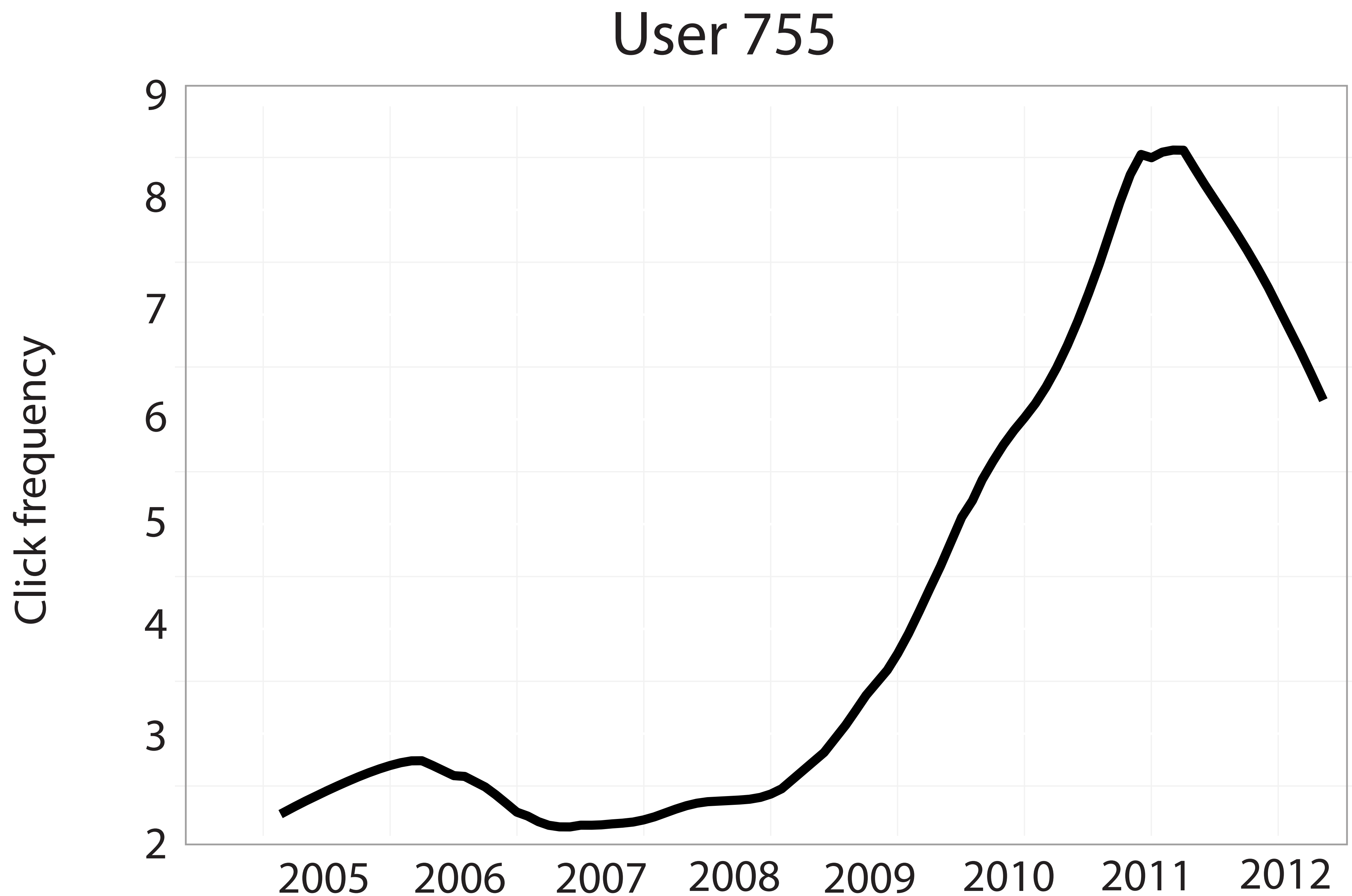


[wikipedia]

Properties of PF

- Suitable for implicit and explicit data

- Model can be fit to massive datasets


User 755
Click frequency
9
8
7
6
5
4
3
2
2005
2006
2007
2008
2009
2010
2011
2012

Dynamic
Poisson factorization

- Users’ preferences evolve over time

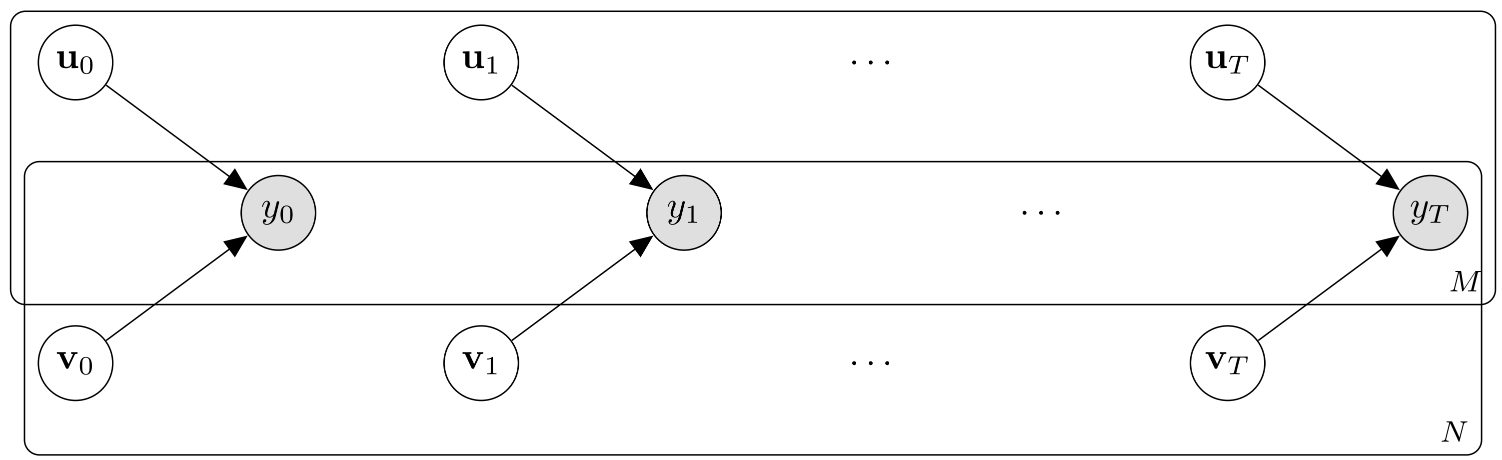
- Item popularity evolves over time

➡ Ratings are not exchangeable over time

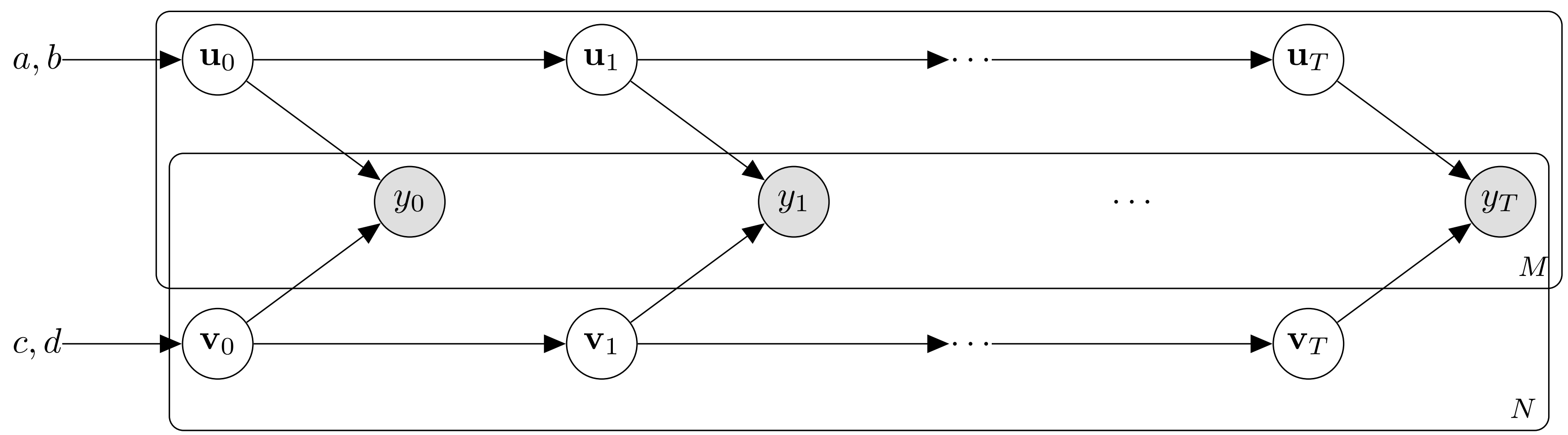
Dynamic Matrix Factorization (DPF)

Dynamic Matrix Factorization (DPF)

Dynamic Matrix Factorization (DPF)



Dynamic Matrix Factorization (DPF)



- Modeling: Smooth evolution through time

Smooth Evolution through time

- Gaussian time series model

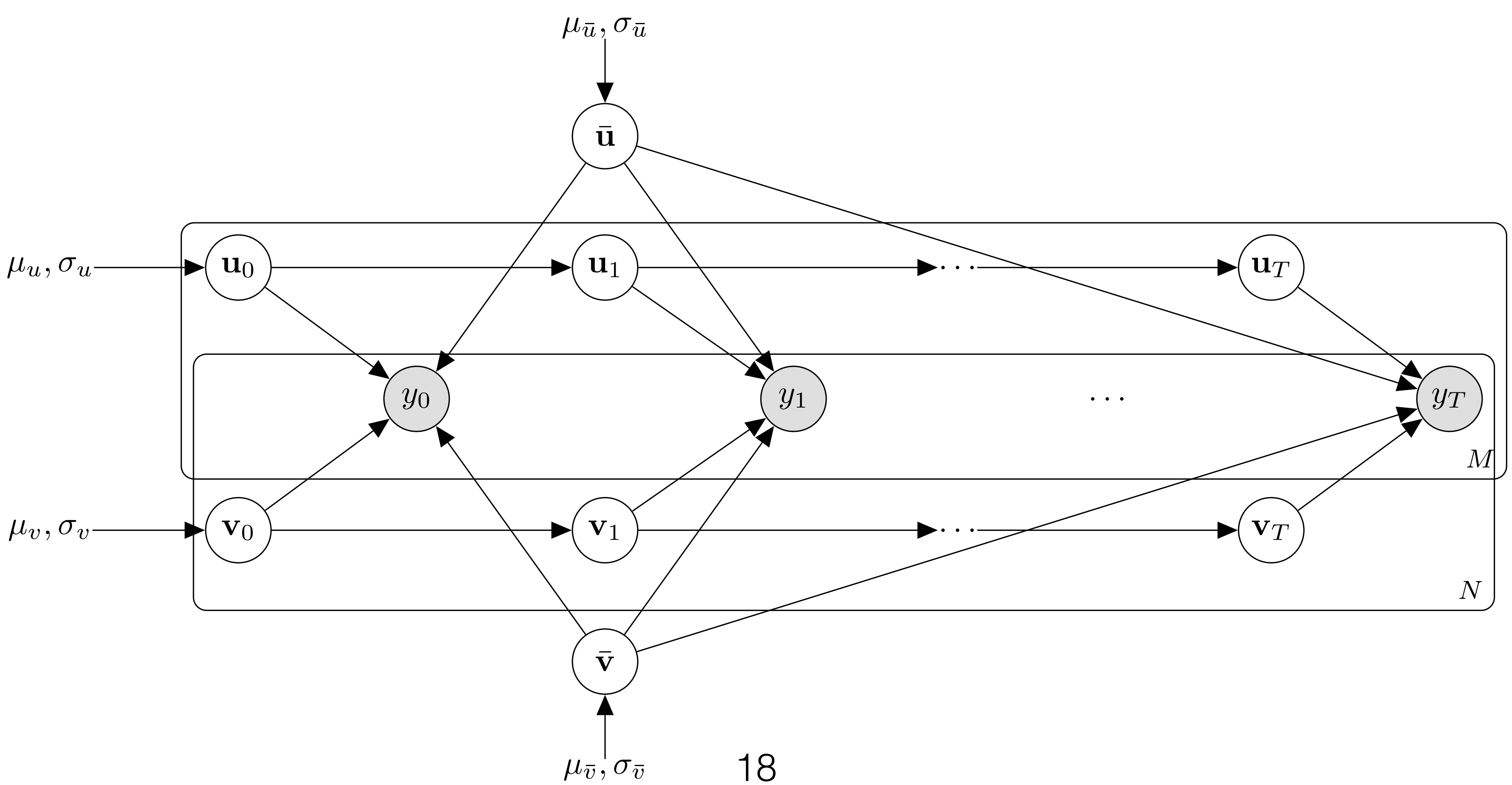
$$\mathbf{u}_{m,t} \mid \mathbf{u}_{m,t-1} \sim \mathcal{N}(\mathbf{u}_{m,t-1}, \sigma_u^2 I)$$

- Exponentiate to obtain positive Poisson rates

$$y_{mn,t} \sim \text{Poisson}\left(\sum_{k=1}^{K} e^{u_{mk,t}} e^{v_{nk,t}}\right)$$

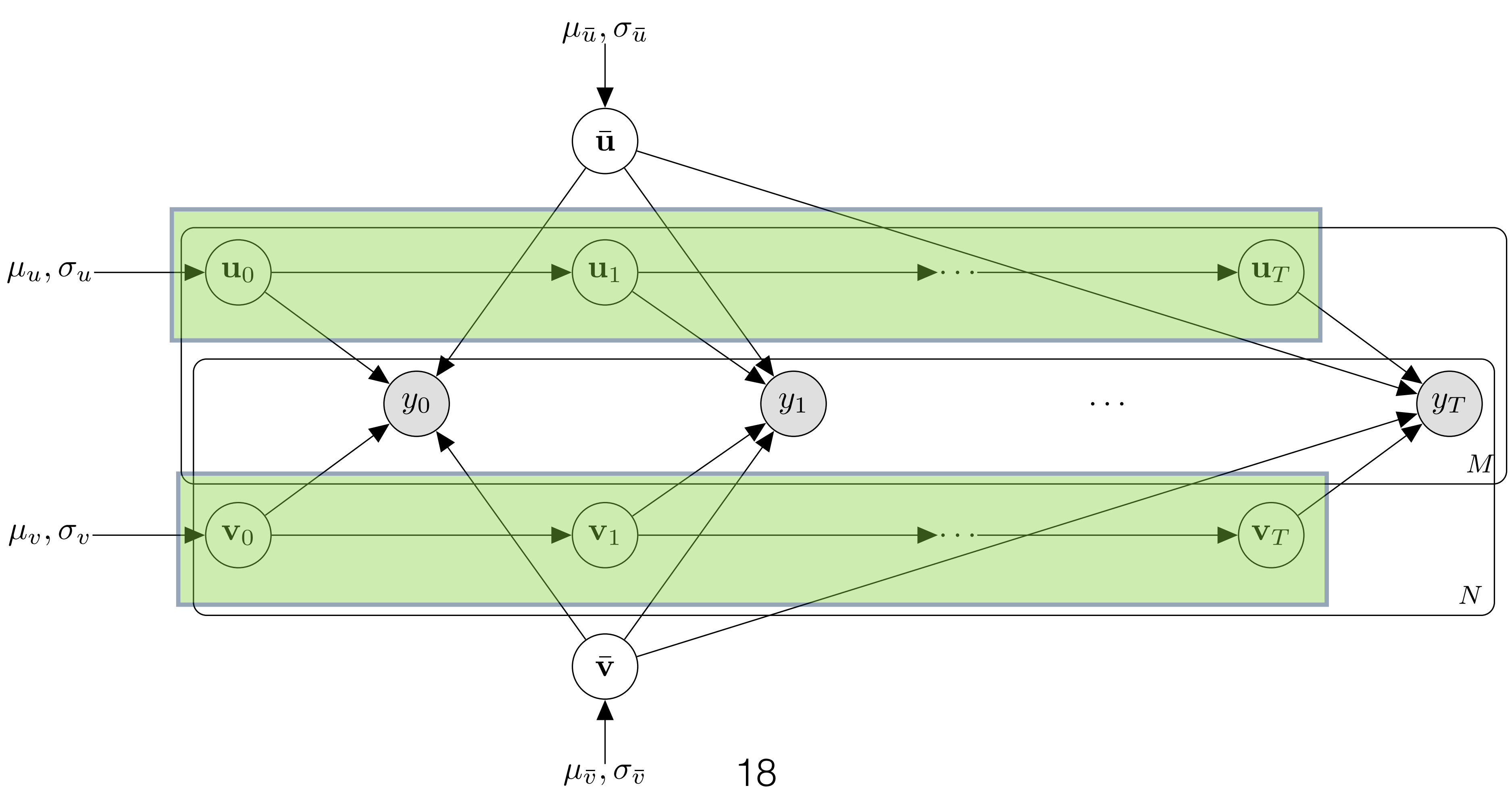
Local and Global factors

- Two levels of modeling:
  - **Local factors**: model evolution through time
  - **Global factors**: model constant preferences wrt time



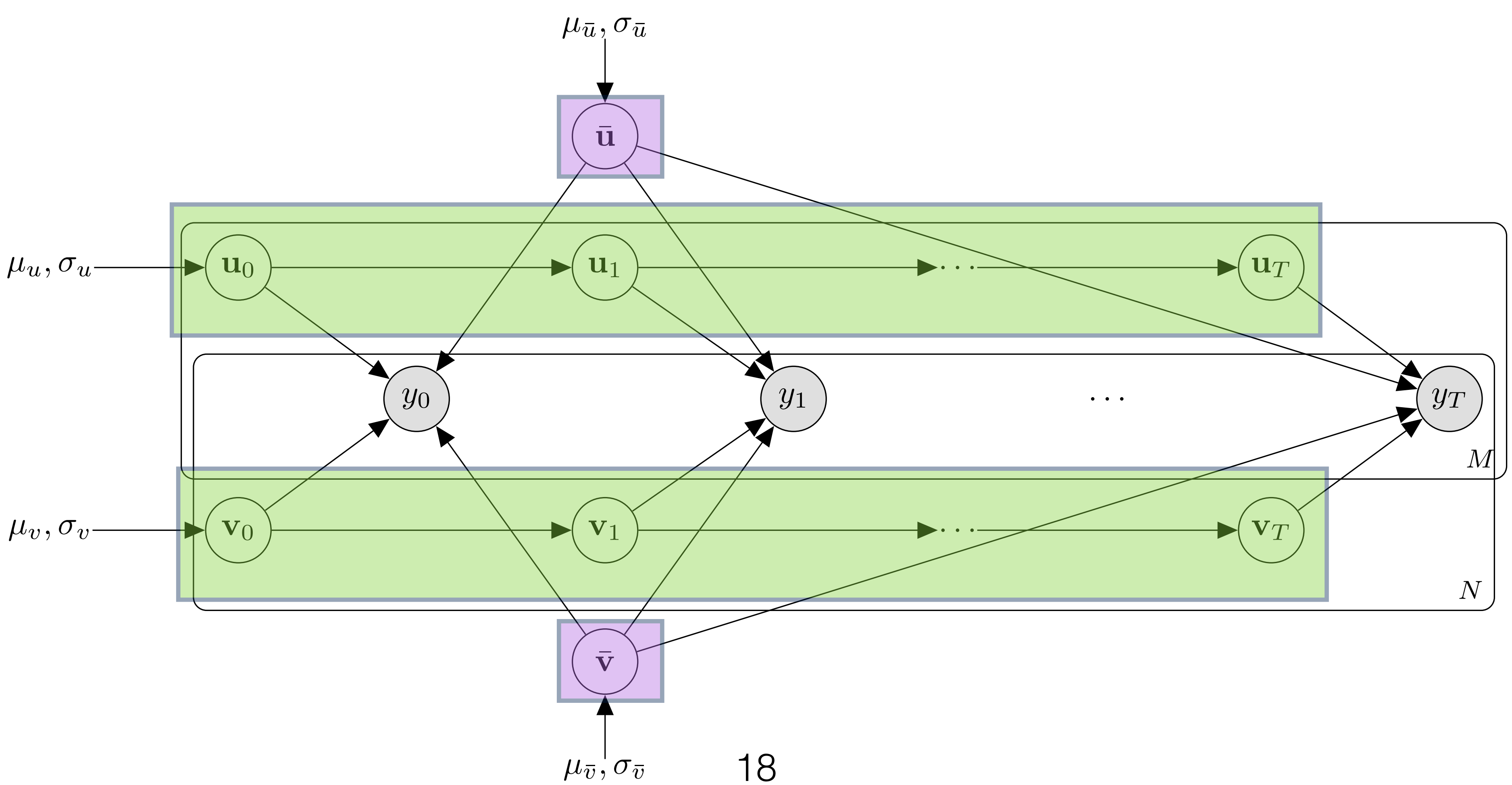
Local and Global factors

- Two levels of modeling:
  - **Local factors**: model evolution through time
  - **Global factors**: model constant preferences wrt time

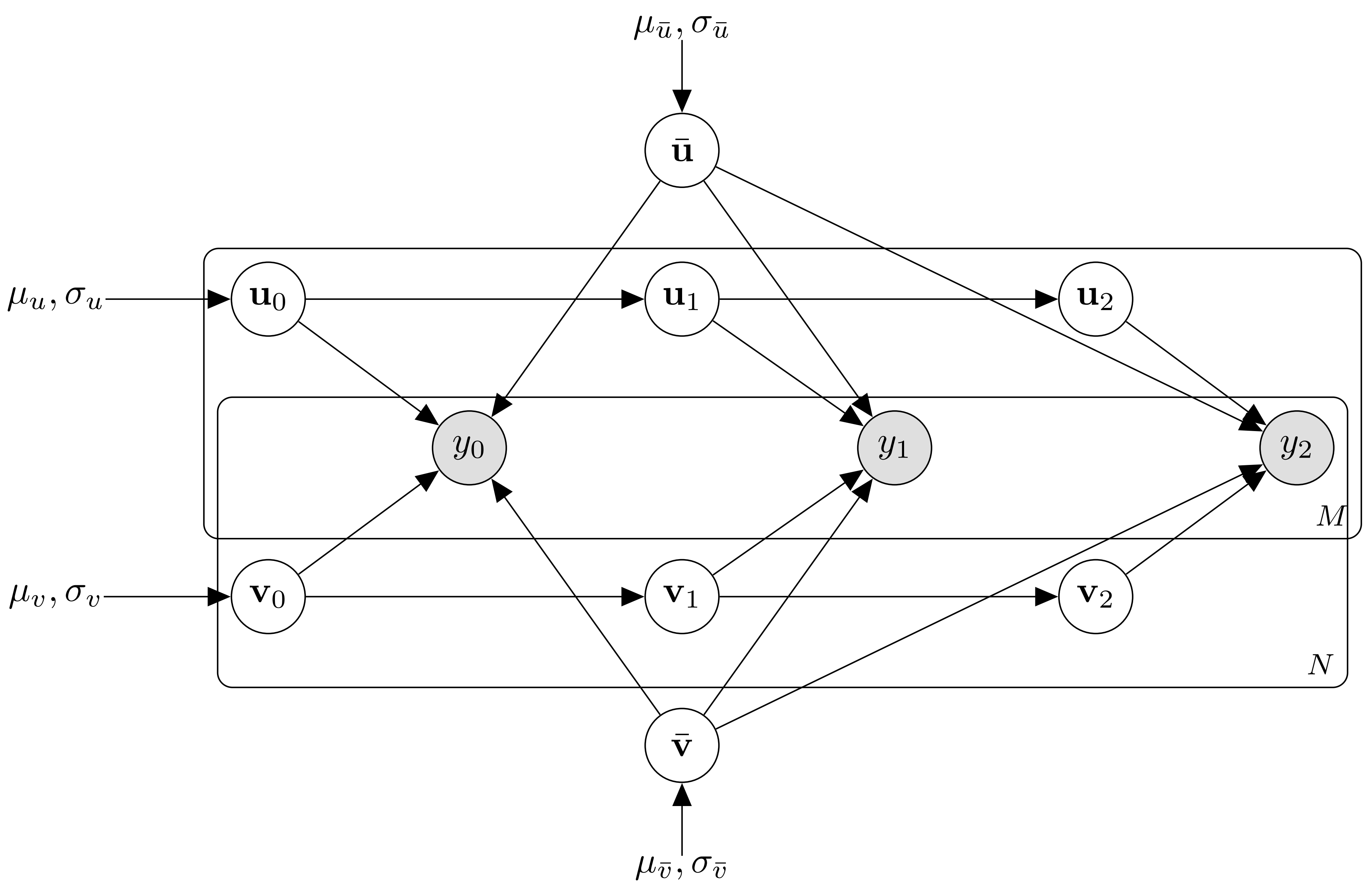


Local and Global factors

- Two levels of modeling:
  - **Local factors**: model evolution through time
  - **Global factors**: model constant preferences wrt time



A 3 timeslice Dynamic PF



Inference

- Variational inference algorithm
  - Mean-field (factorized) approximation
  - Non-conjugacy between $P(\mathbf{u}_t \mid \mathbf{u}_{t-1})$ and $P(\mathbf{y}_t \mid \mathbf{u}_t, \mathbf{v}_t)$
    - Use an additional approximation
- See the paper for details on the algorithm
- Scales linearly in time, we provide a parallel implementation

Empirical results

- Explicit data
  - Augmented matrix factorization [Koren'10, Li'11, Gultekin'14]
  - Tensor factorization [Karatzoglou'10]
    - **Bayesian Tensor Probabilistic Factorization [Xiong'10]**
- Implicit data
  - HMM [Sahoo'12]
  - Gamma process MF [Acharya'15]
- DPF (us):
  - User and item dynamicity
  - Implicit and explicit
  - Scalable

Experimental setup

- Test on multiple time steps
  - Train data: clicks up to time slice t
  - Predict held-out clicks at time t+1
- Metrics for implicit data
  - Ranking-based (NDCG, Recall, MAR, MRR)

Netflix-time

	Recall@50	MAR	MRR	NDCG
dPF	**0.170**	**640**	**0.027**	**0.294**
BPTF [Xiong'10]	0.148	668	0.020	0.277
PF-all [Gopalan'15]	0.145	691	0.021	0.280
PF-last [Gopalan'15]	0.065	807	0.019	0.268

- 7.5K users, 3.6K items, 2M non-zero ratings, binarized
- 3 months per time slice

Netflix

	Recall@50	MAR	MRR	NDCG
dPF	**0.156**	**1605**	**0.021**	**0.358**
PF-all [Gopalan'15]	0.120	1807	0.015	0.338
PF-last [Gopalan'15]	0.138	1635	0.018	0.351

- 225K users, 14K items, 6.9M non-zero ratings, binarized
- 6 months per time slice

arXiv

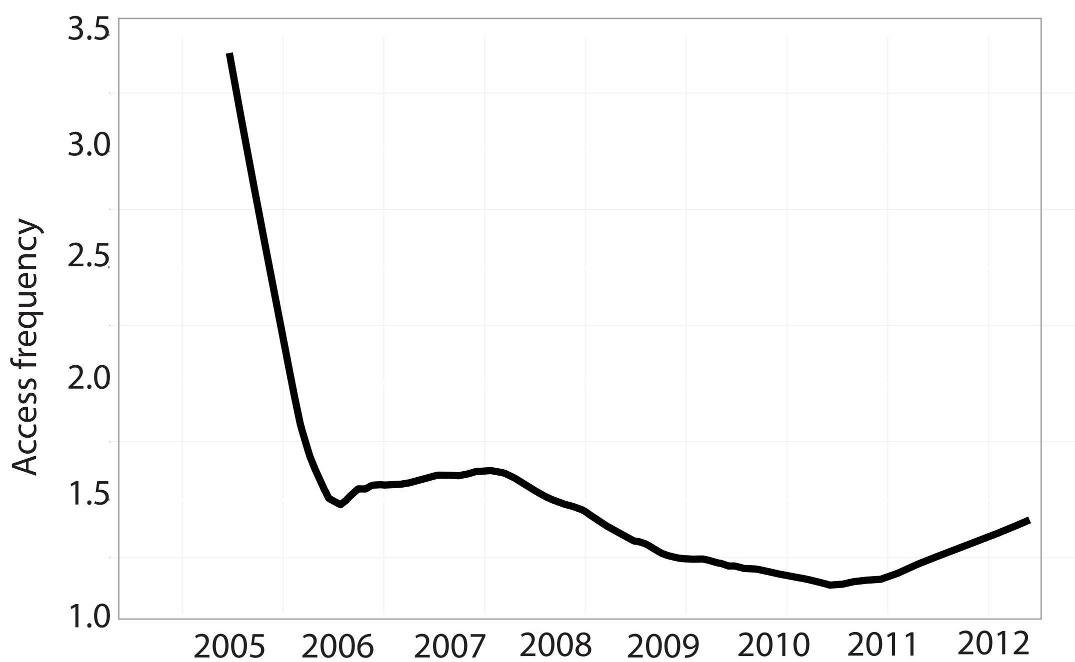
	Recall@50	MAR	MRR	NDCG
dPF	**0.035**	**21822**	**0.0062**	**0.186**
PF-all [Gopalan'15]	0.032	22402	0.0056	0.182
PF-last [Gopalan'15]	0.023	25616	0.0040	0.168

- 75K users, 5K items, 1.3M clicks
- 18 months per time slice

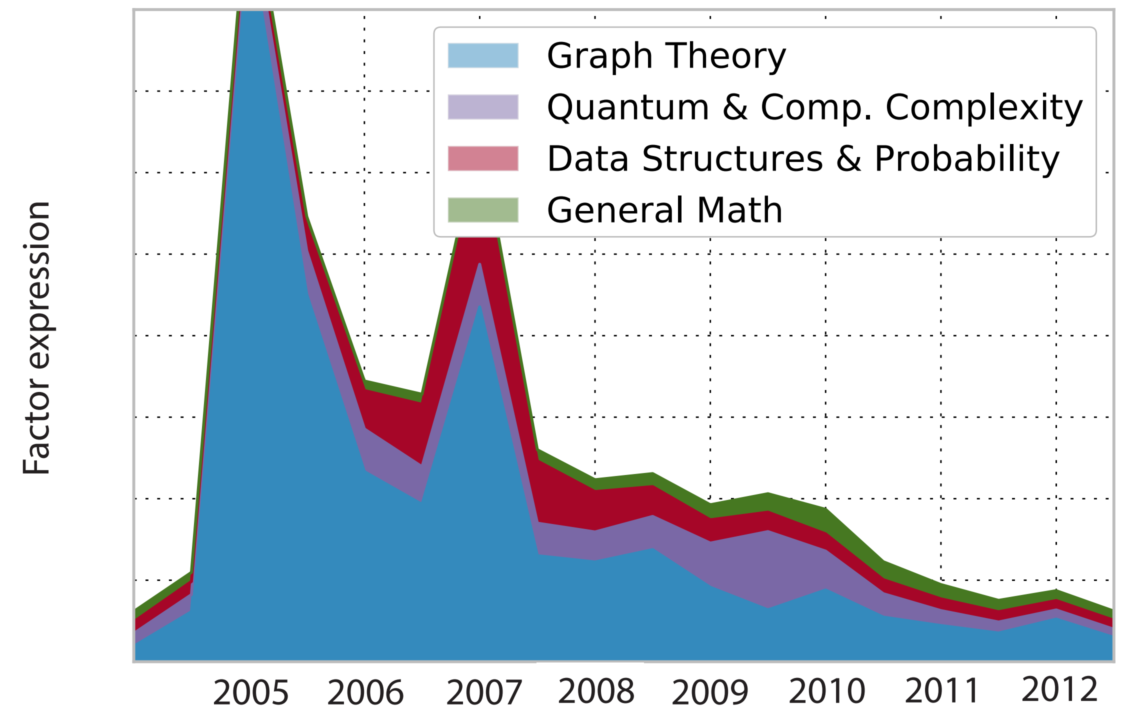
Usage Data

The Google Similarity effect

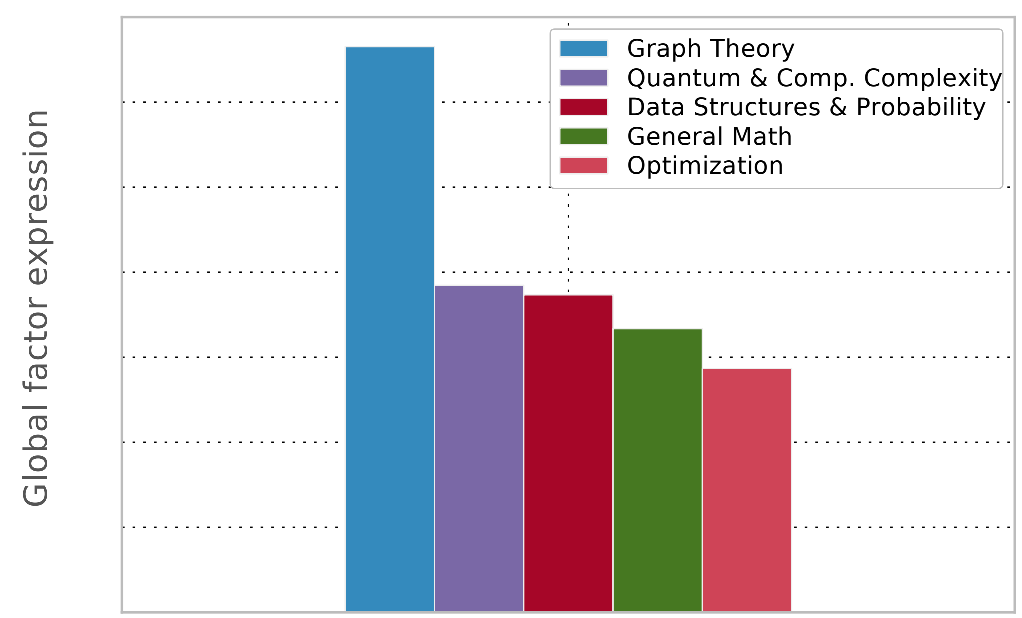
arXiv: cs/0412098



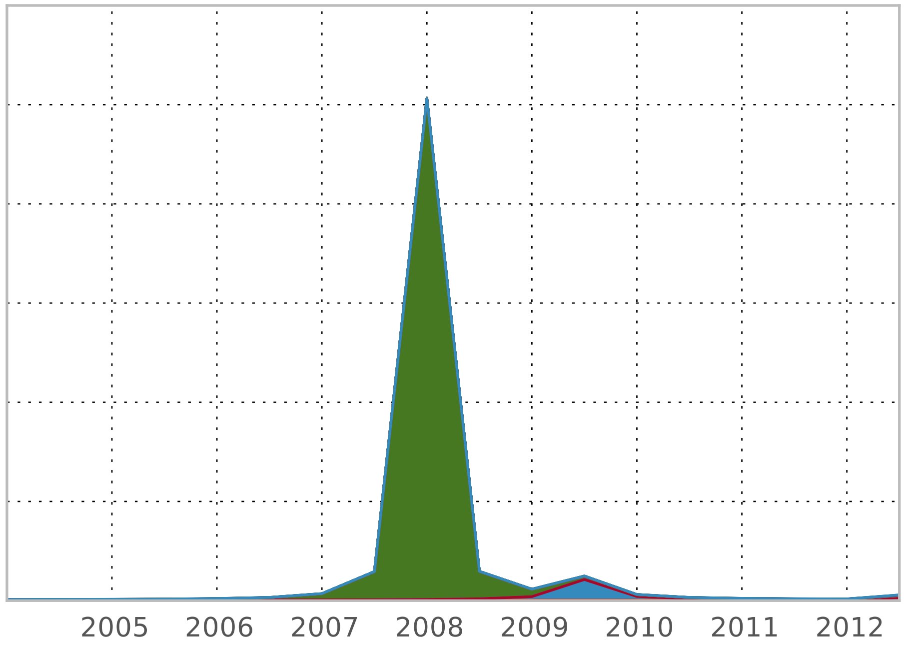
DPF Factors

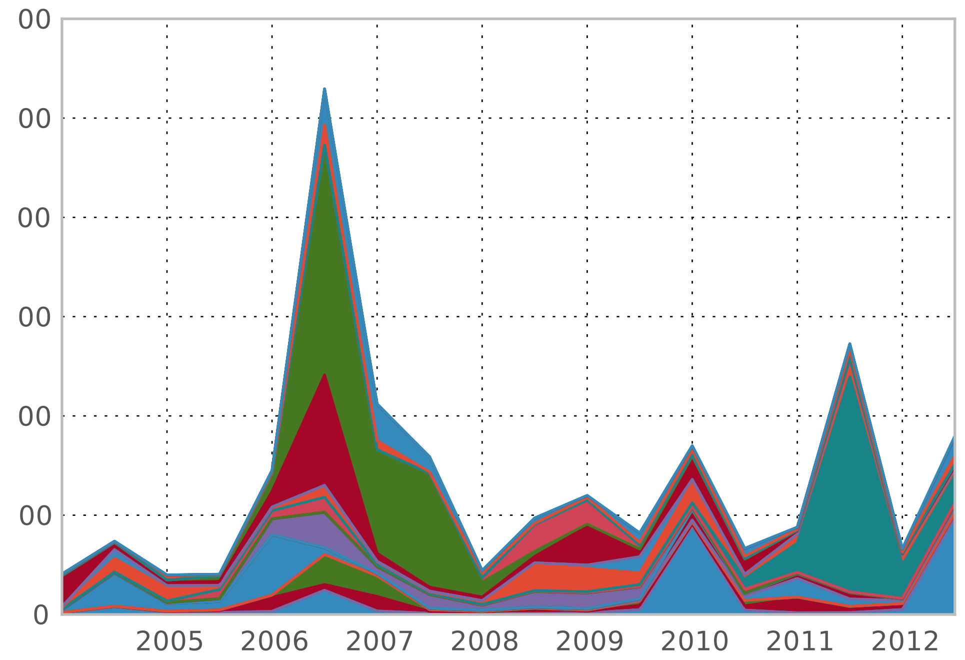


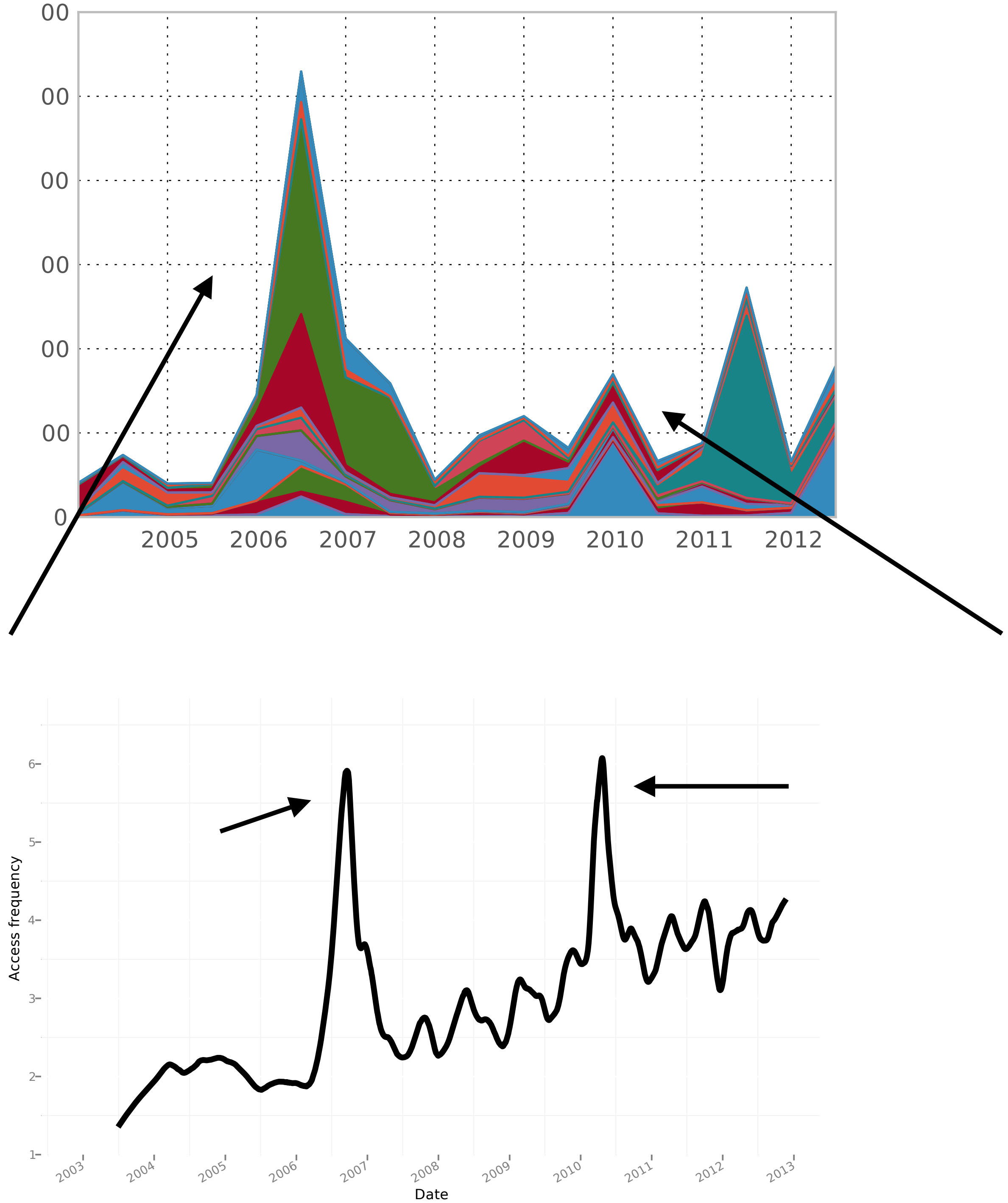
DPF Global Factors



Paper Selected at Random




00
00
00
00
00
00
0
2005
2006
2007
2008
2009
2010
2011
2012

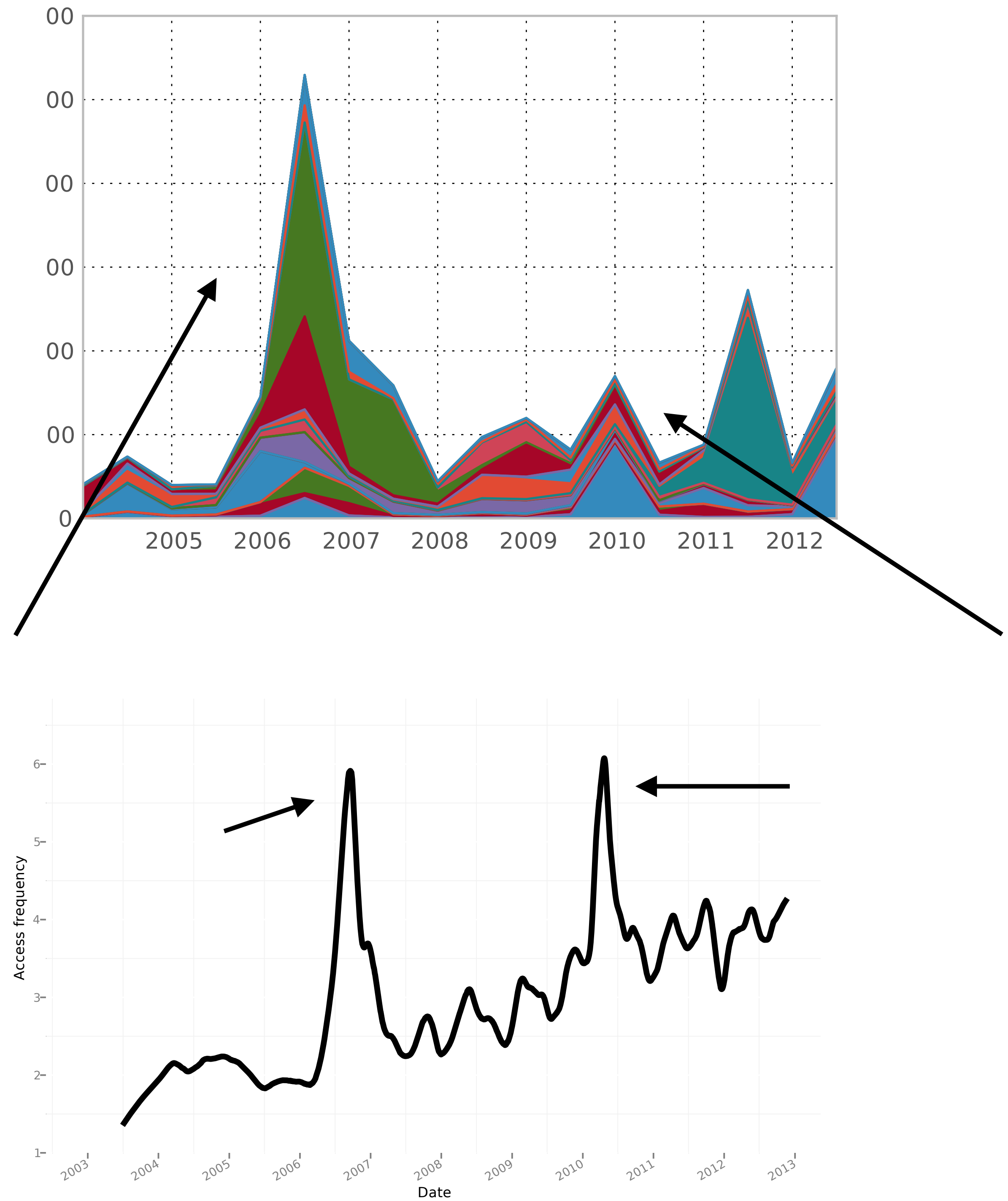

00
00
00
00
00
00
0
2005
2006
2007
2008
2009
2010
2011
2012
Access frequency
6
5
4
3
2
1
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Date

arXiv.org > math > arXiv:math/0211159

Mathematics > Differential Geometry

The entropy formula for the Ricci flow and its geometric applications

Grisha Perelman

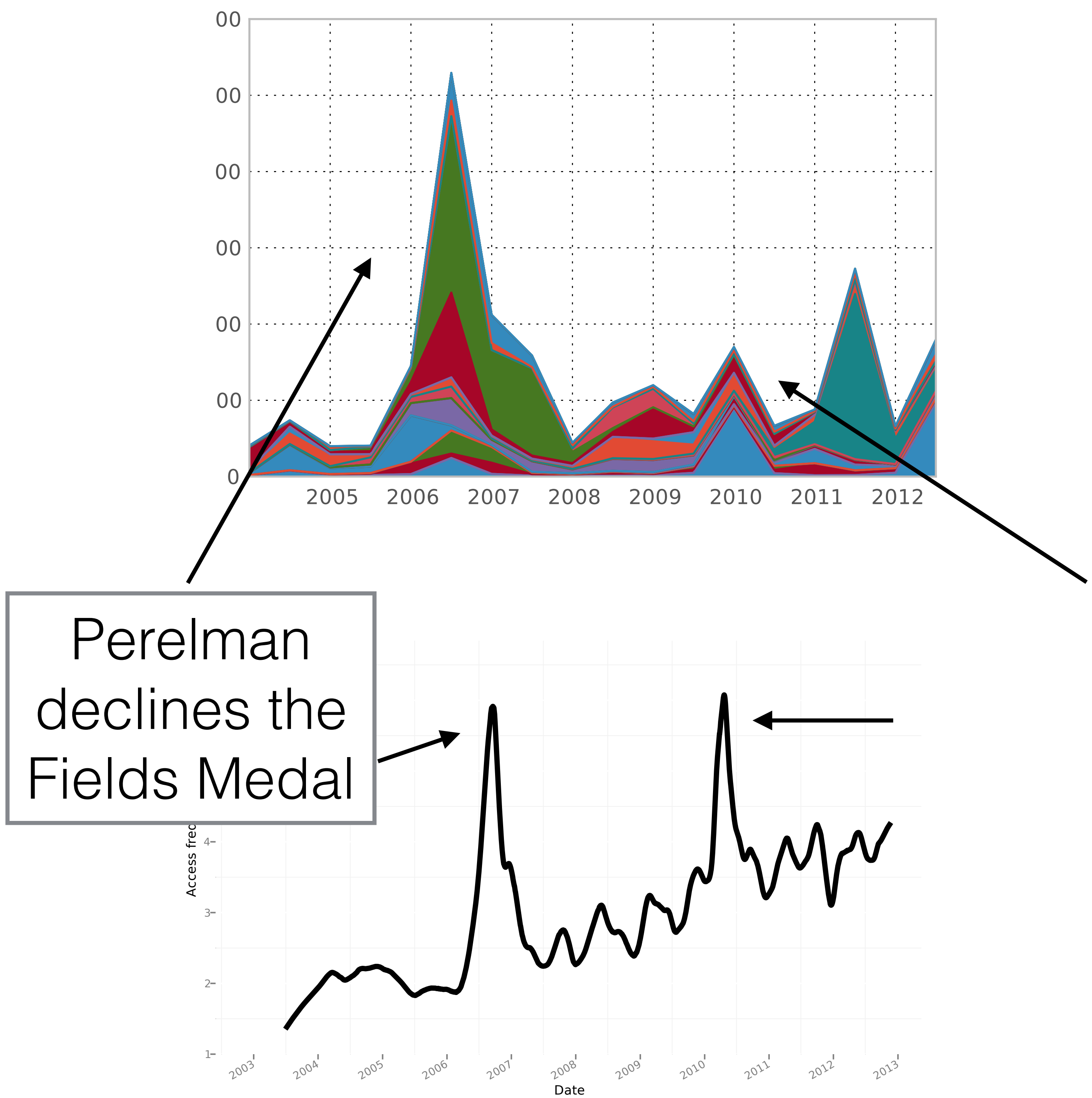


arXiv.org > math > arXiv:math/0211159

Mathematics > Differential Geometry

The entropy formula for the Ricci flow and its geometric applications

Grisha Perelman

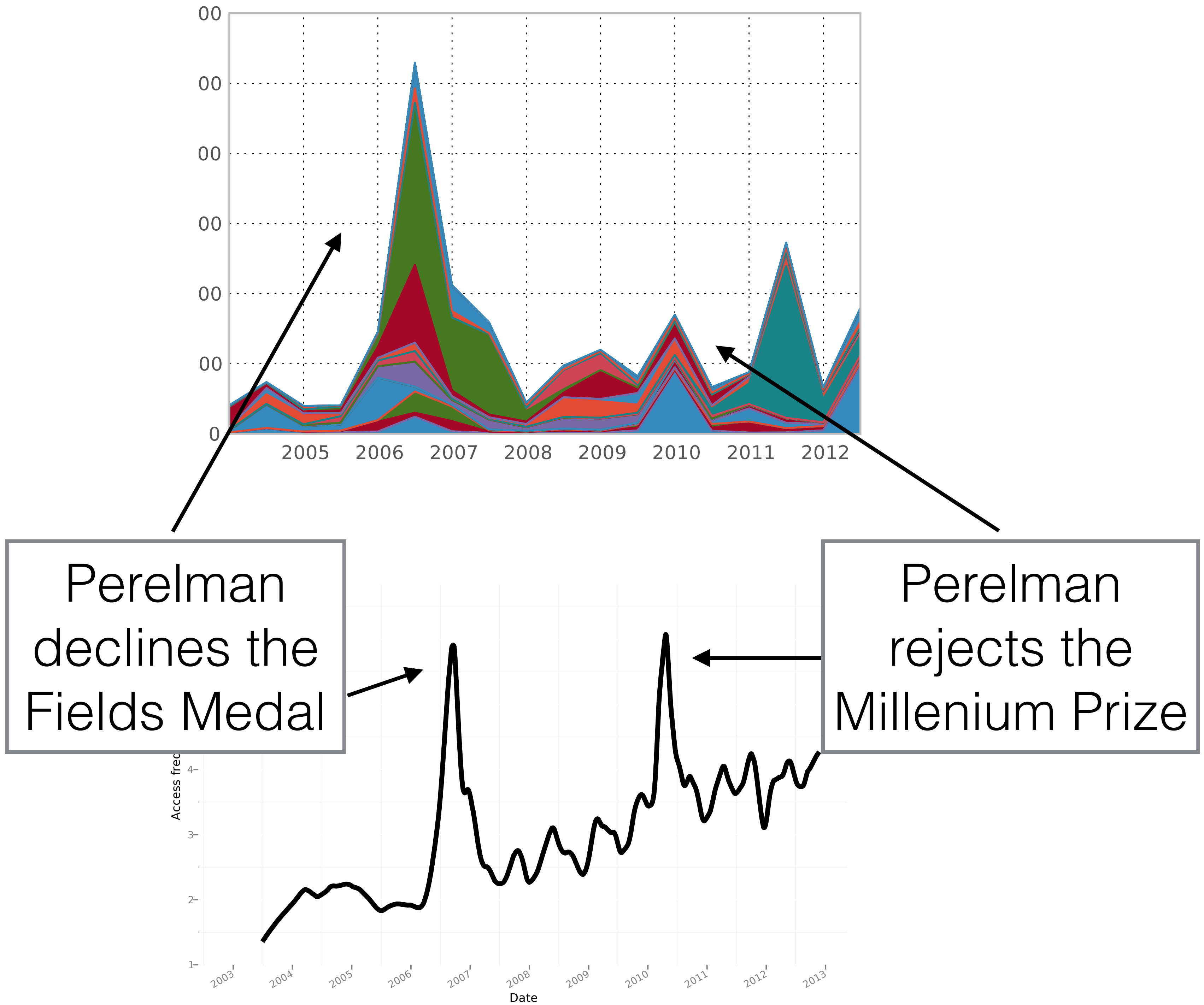


arXiv.org > math > arXiv:math/0211159

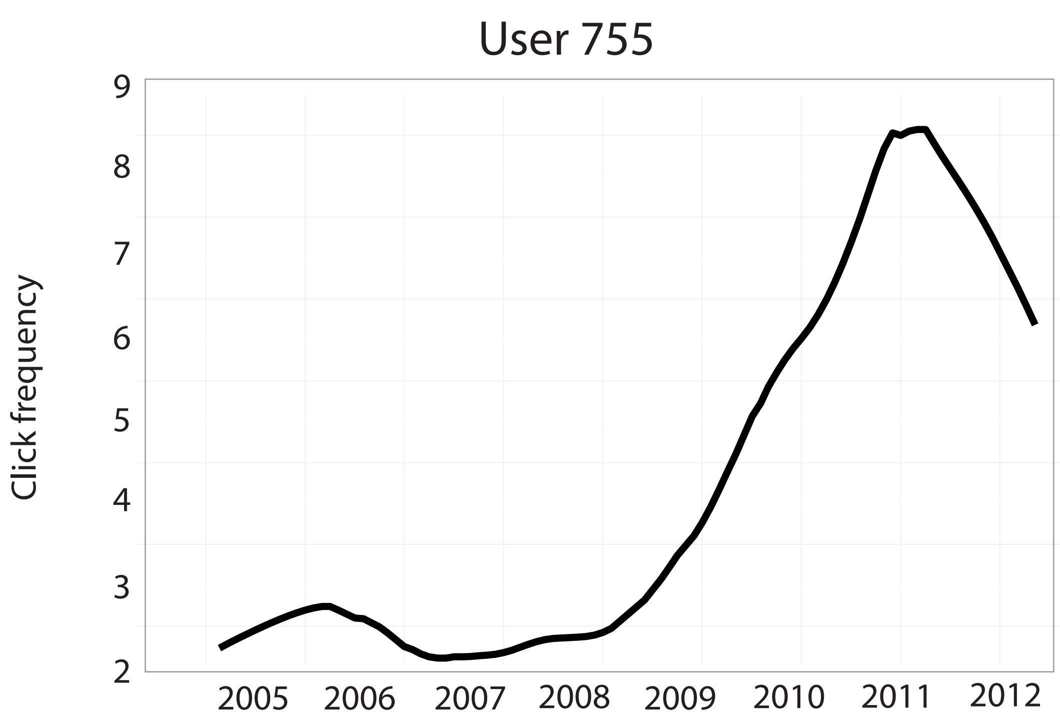
Mathematics > Differential Geometry

The entropy formula for the Ricci flow and its geometric applications

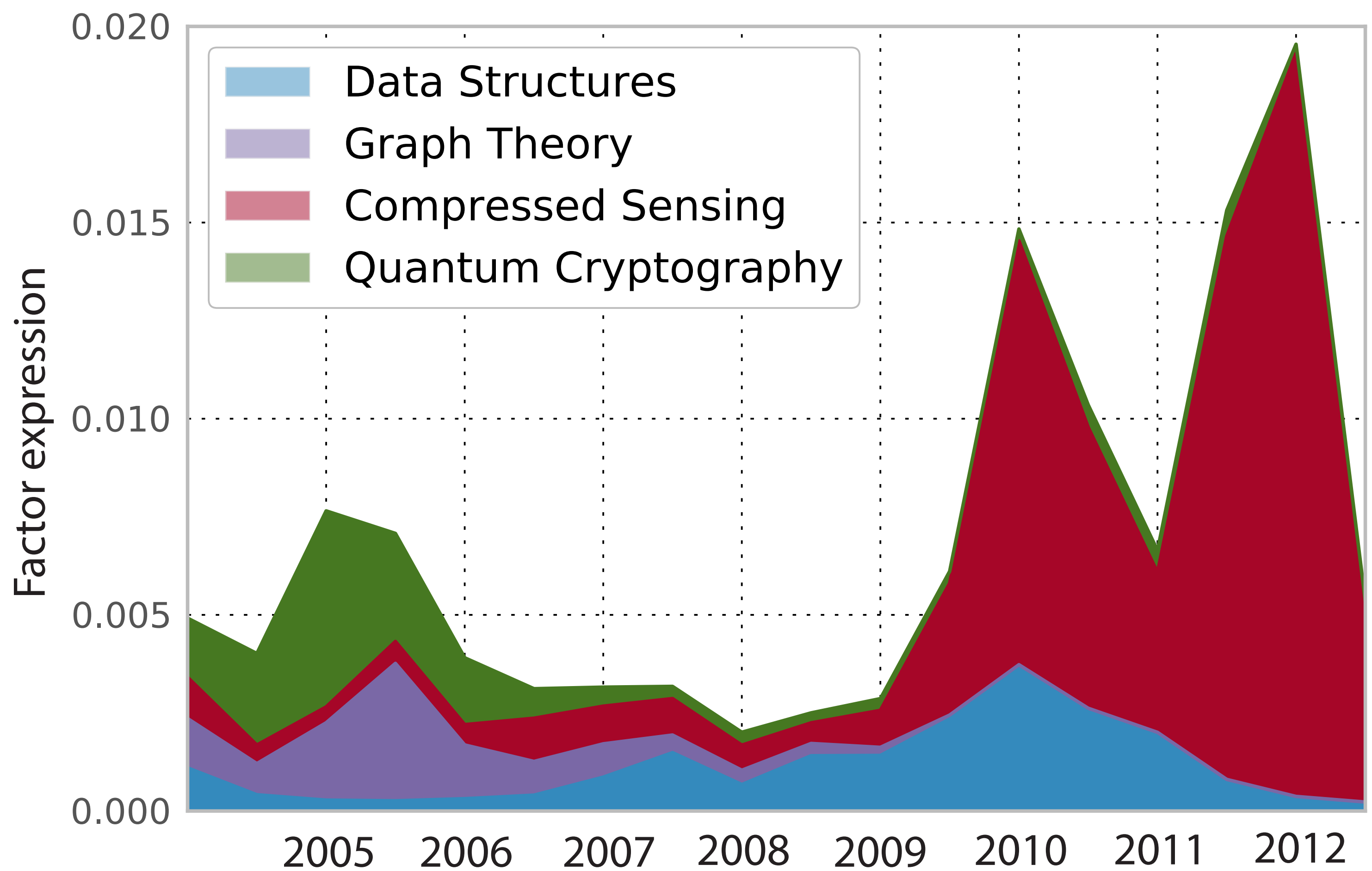
Grisha Perelman



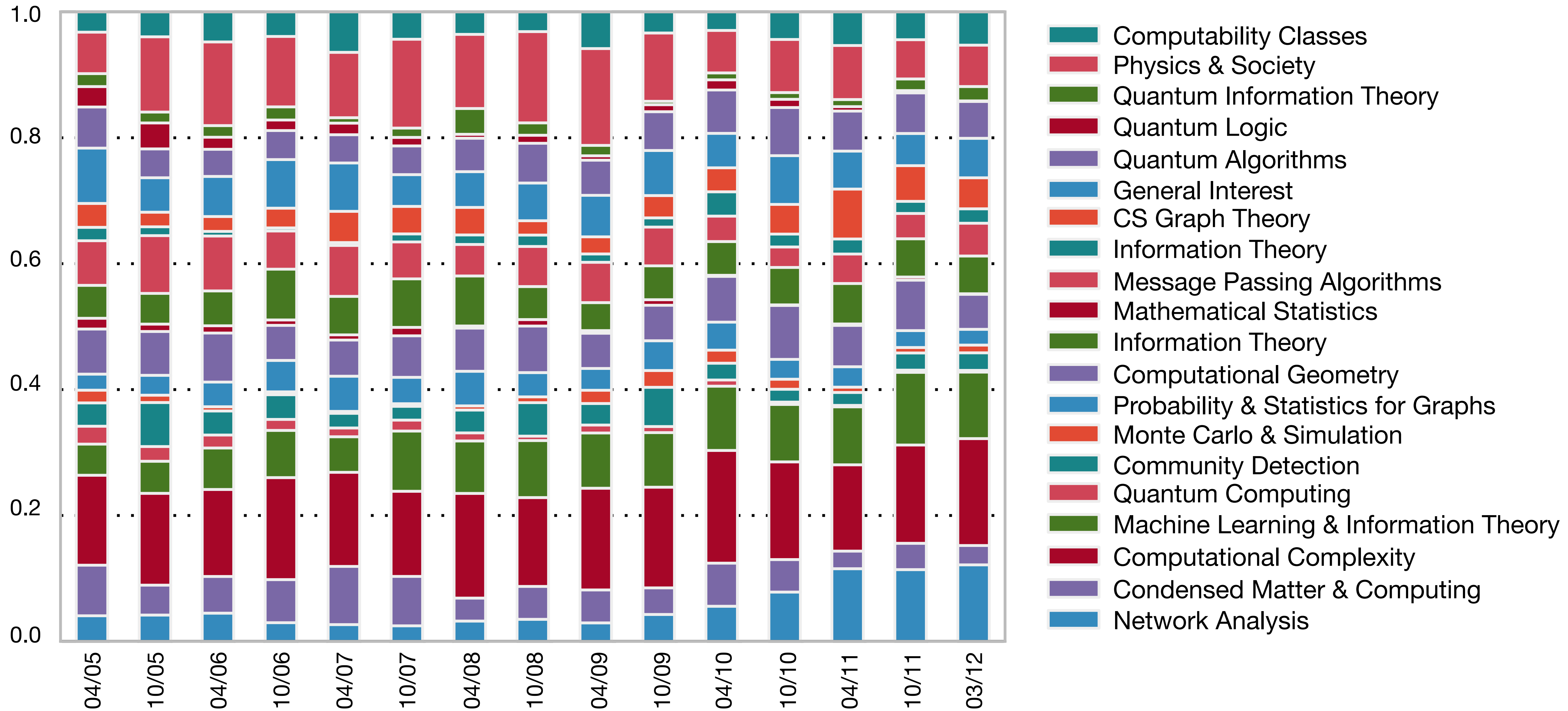
Usage Data



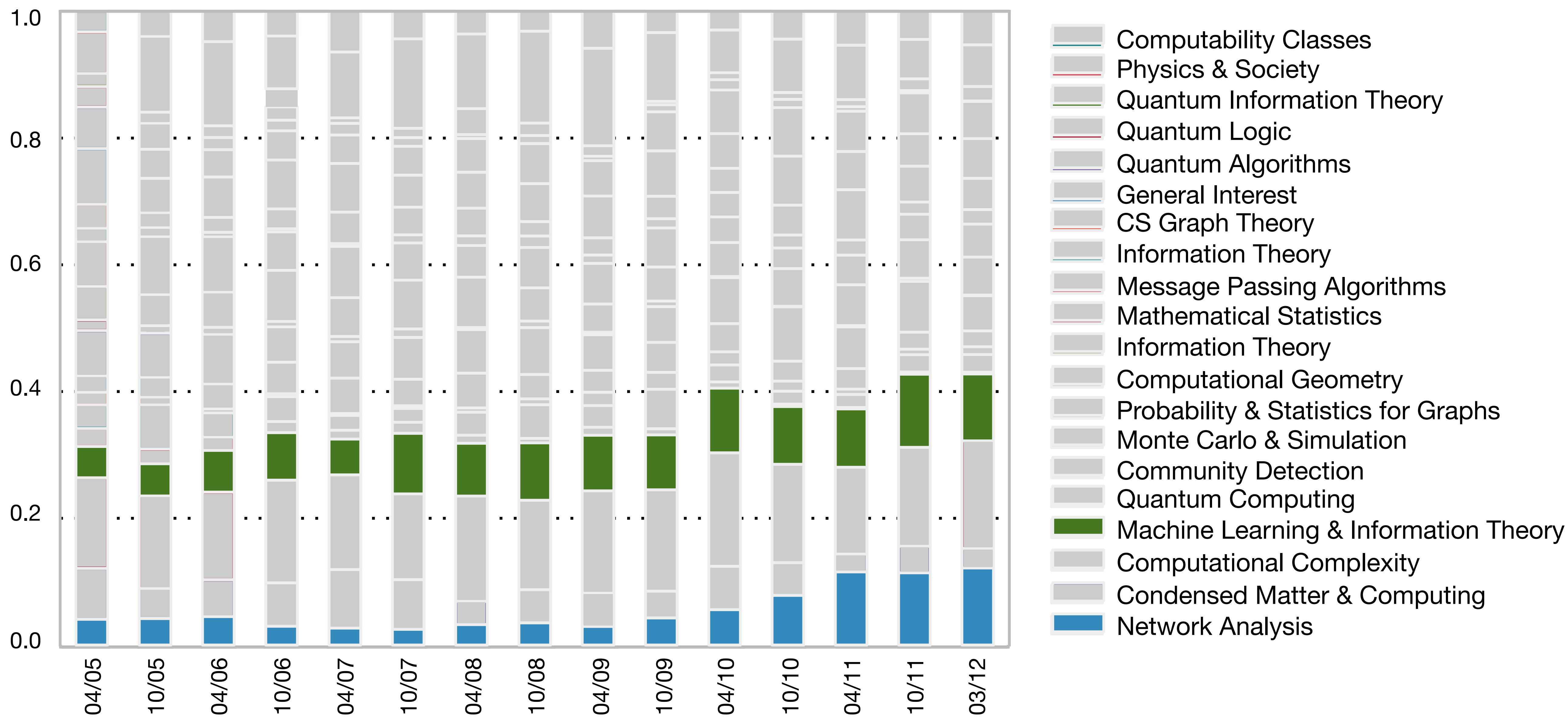
DPF Factors



Fields evolve over time

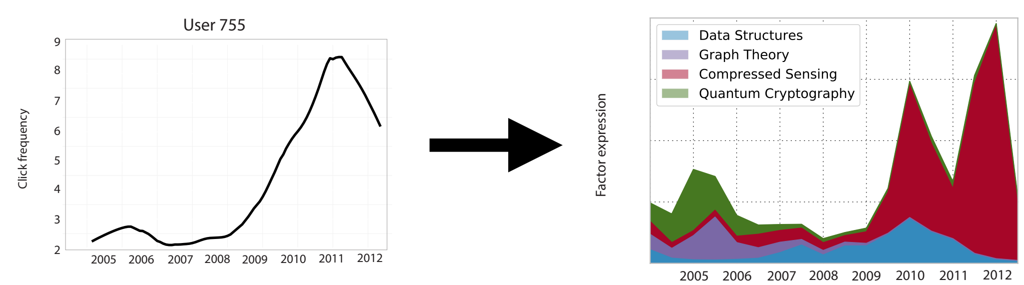


Fields evolve over time



Conclusions

- Dynamic Poisson factorization (DPF)



  - Implicit data, scalable

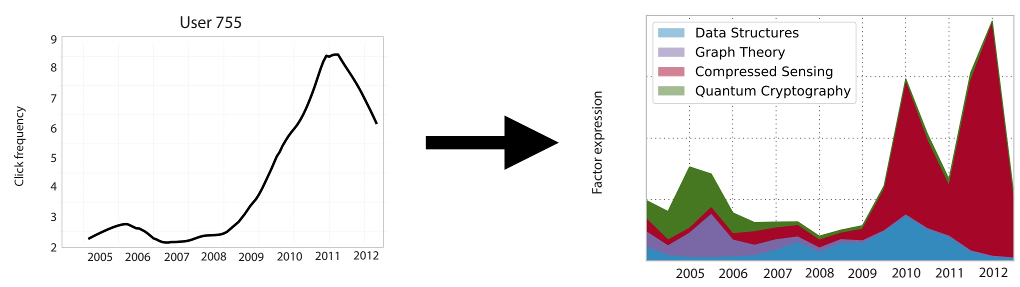
- Open source implementation is available:

  github.com/Blei-Lab/

- Future work: levels of granularities, continuous time

Thank you!

- Dynamic Poisson factorization (DPF)



  - Implicit data, scalable

- Open source implementation is available:

github.com/Blei-Lab/

- Future work: levels of granularities, continuous time