



Social and Technological Network Analysis

Lecture 11: Spatial and Social Network Analysis

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In This Lecture



- In this lecture we will study spatial networks and geo-social networks through examples from our work.

Places and Friends



foursquare Search people and places...

Activity Explore Lists Cecilia ▾

Computer Lab, University of Cambridge

15 JJ Thompson Avenue, Cambridge, UK CB3 0FD
University (Edit)

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SAVE

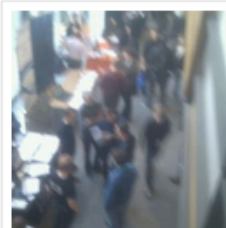
DONE

YOUR CHECK-INS	TOTAL PEOPLE	TOTAL CHECK-INS
57	120	1,197

Mayor: Chloë
44 check-ins in last 60 days **14 friends have been here**
Similar places
[Imperial College](#), [Queens' College](#), [Sidney Sussex College](#), [Newnham College](#), [Fitzwilliam College](#)**Share this venue**
☒ [Share with Friends](#)

Photos

[See all 18 photos](#)



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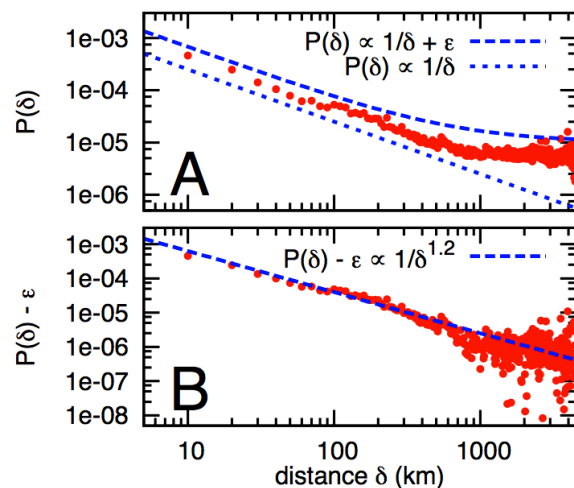
Geo-social Network Analysis can lead to insights into social behaviour



Effect of Distance on Social Connections

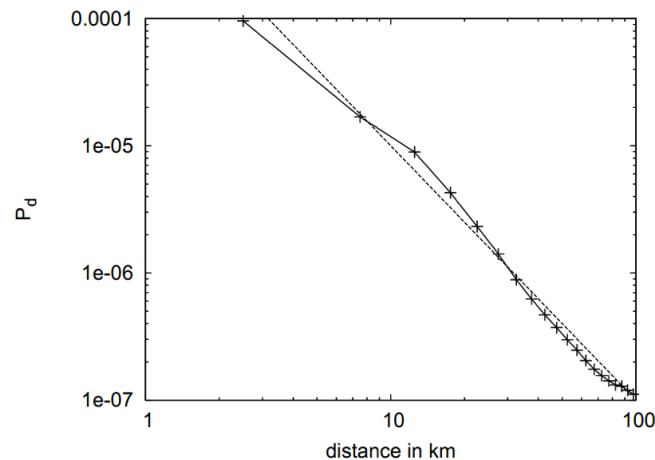


LiveJournal (2005)



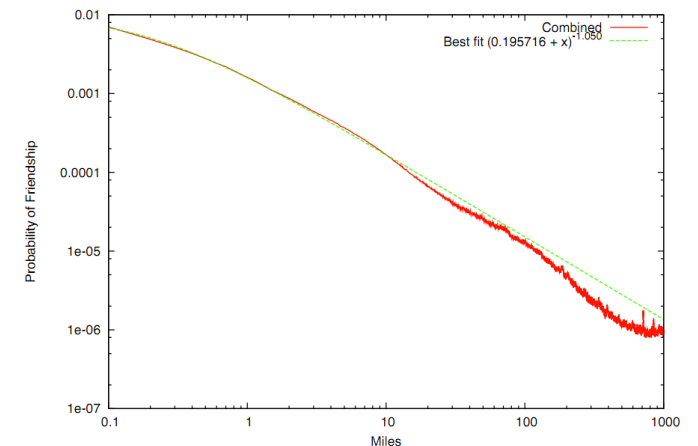
$$P(d) \propto d^{-1} + \epsilon$$

Mobile phones (2008)



$$P(d) \propto d^{-2}$$

Facebook (2010)



$$P(d) \propto d^{-1}$$



Effect of geography over social link formation

What do we see in Geo-social Networks?

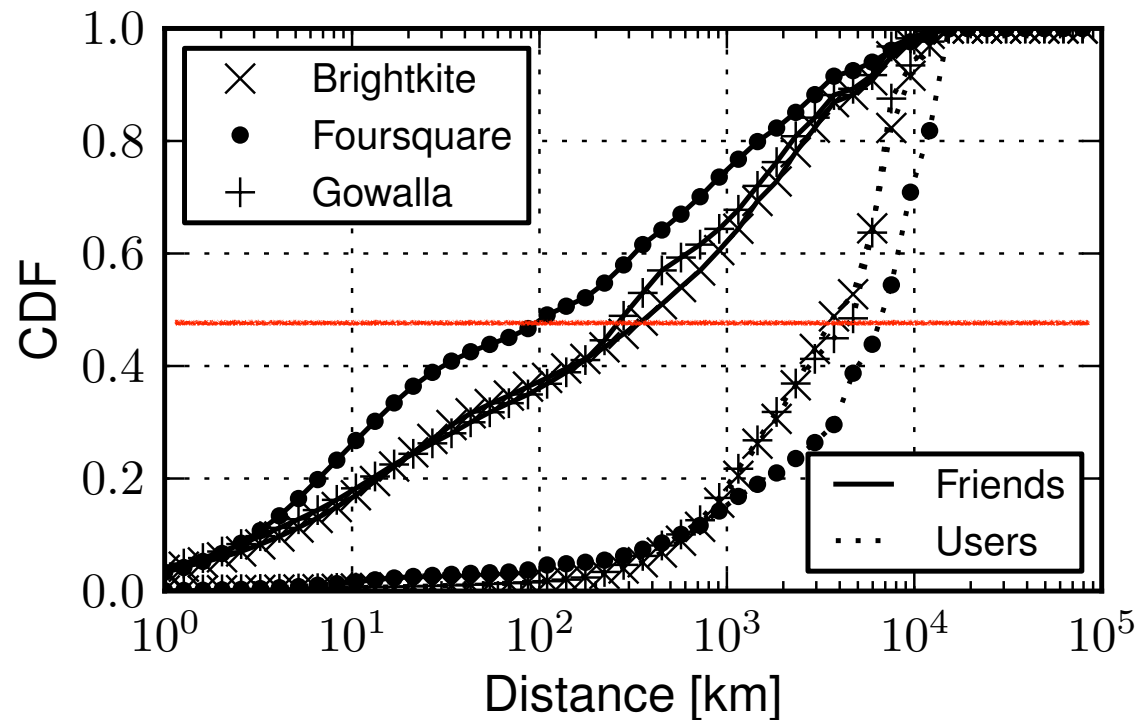


- We have acquired data about the socio-spatial network of **3 real-world location-based services**
- We design **two randomized models** of a socio-spatial network to better understand which factors shape the real networks.
- We study how individual users create their **social links** and their **social triangles** over space.

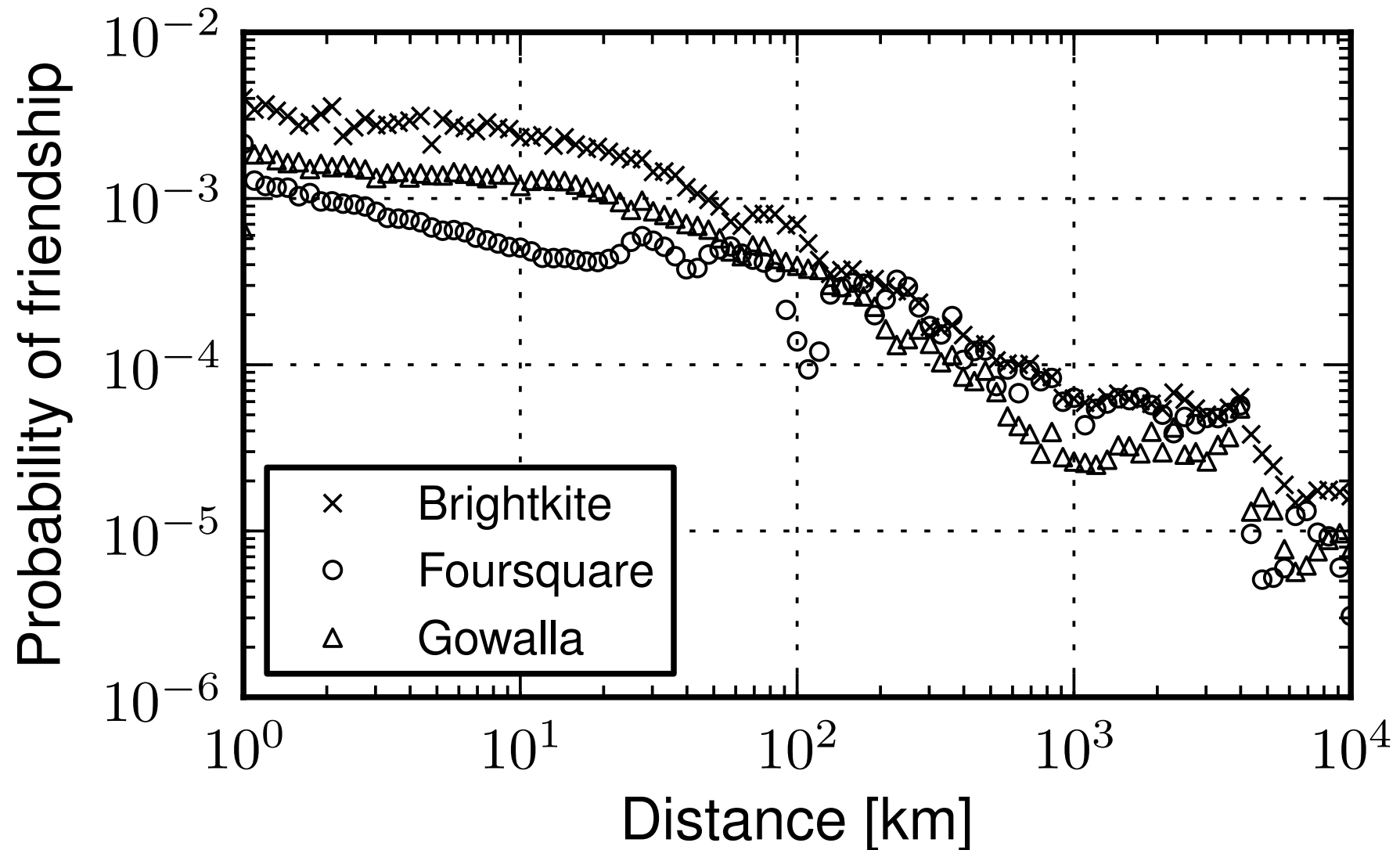
Distance between Friends



Friends tend to be much closer than random users: about 50% of social links span less than 100 km, while about 50% of users are more than 4,000 km apart.



Probability of Friendship vs Distance



Network Randomization



	Description	Social properties	Spatial properties
Original data	No modification.	✓	✓
Geo model	Fix node locations and reassign all links according to probability $P(d)$.	✗	✓
Social model	Fix links and shuffle all node locations.	✓	✗



Users have heterogeneous friend distances

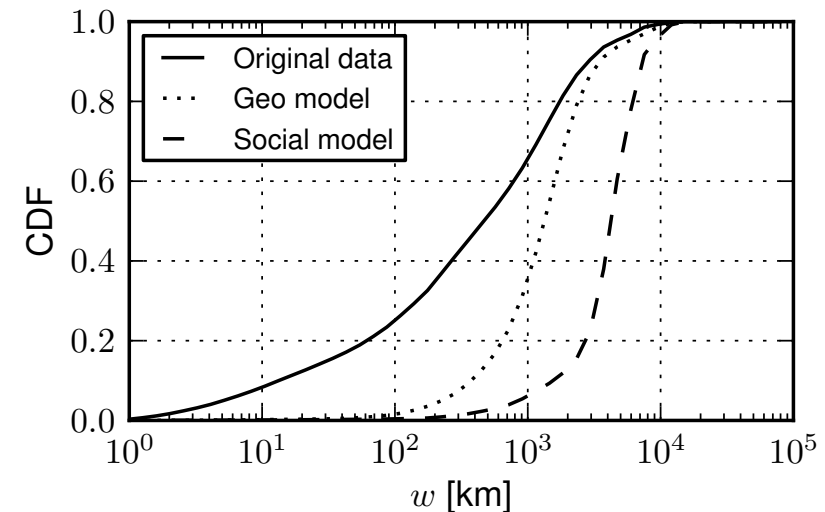
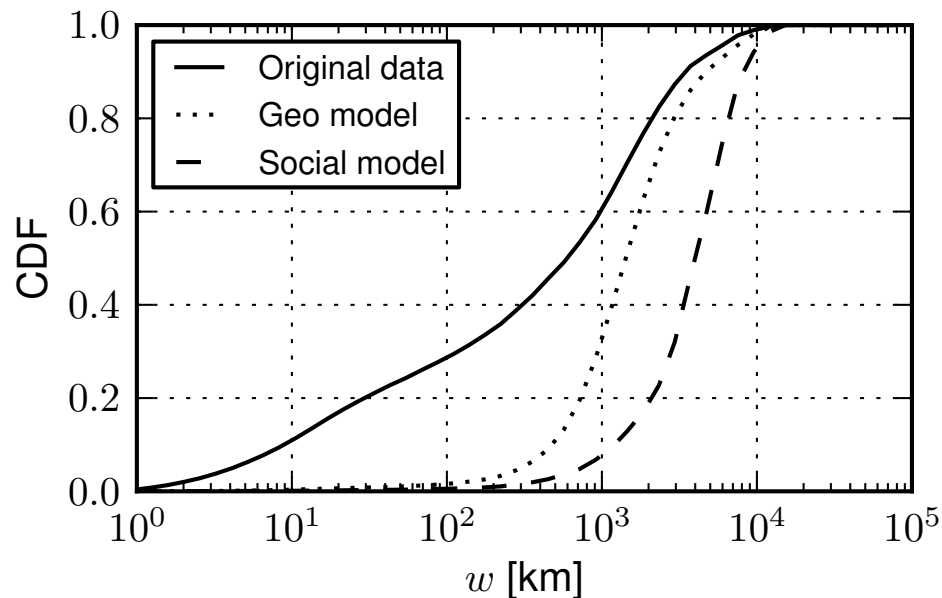
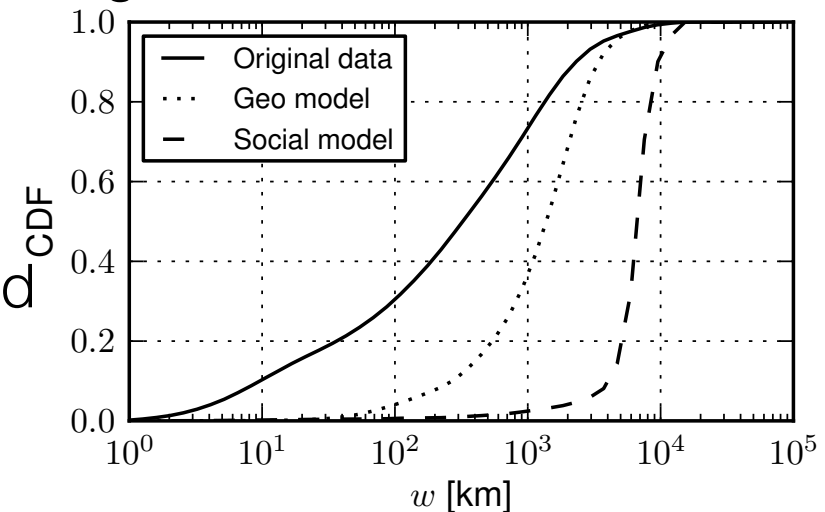


$$w_i = \frac{1}{k_i} \sum_{j \in \Gamma_i} l_{ij}$$

Node degree k_i (indicated by an arrow pointing to the denominator)

Link length l_{ij} (indicated by an arrow pointing to the summand)

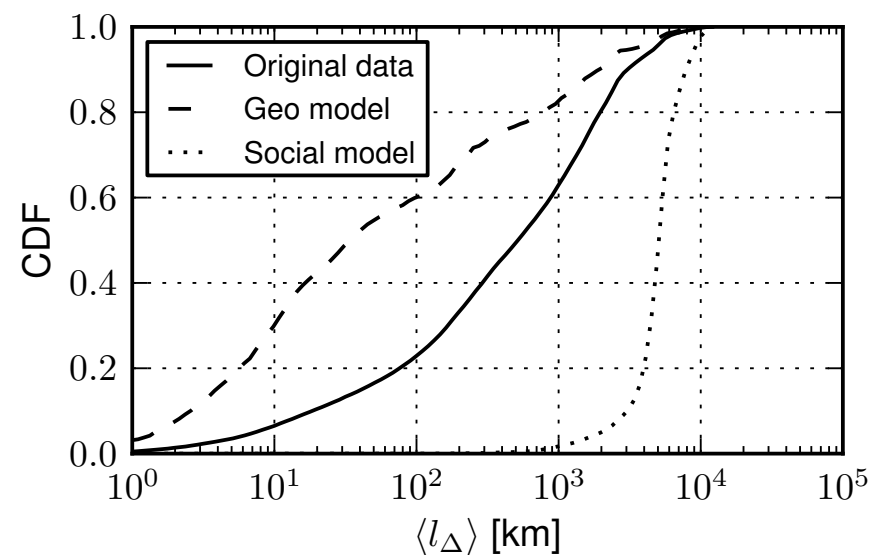
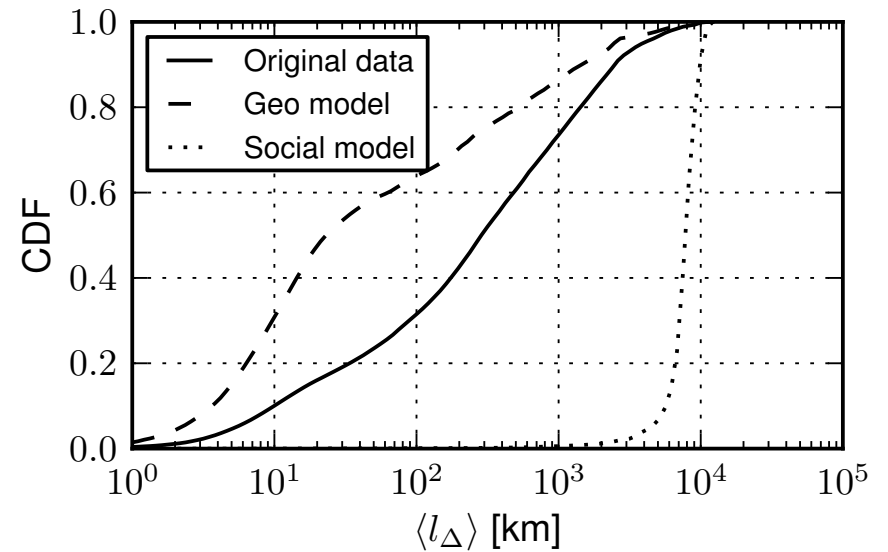
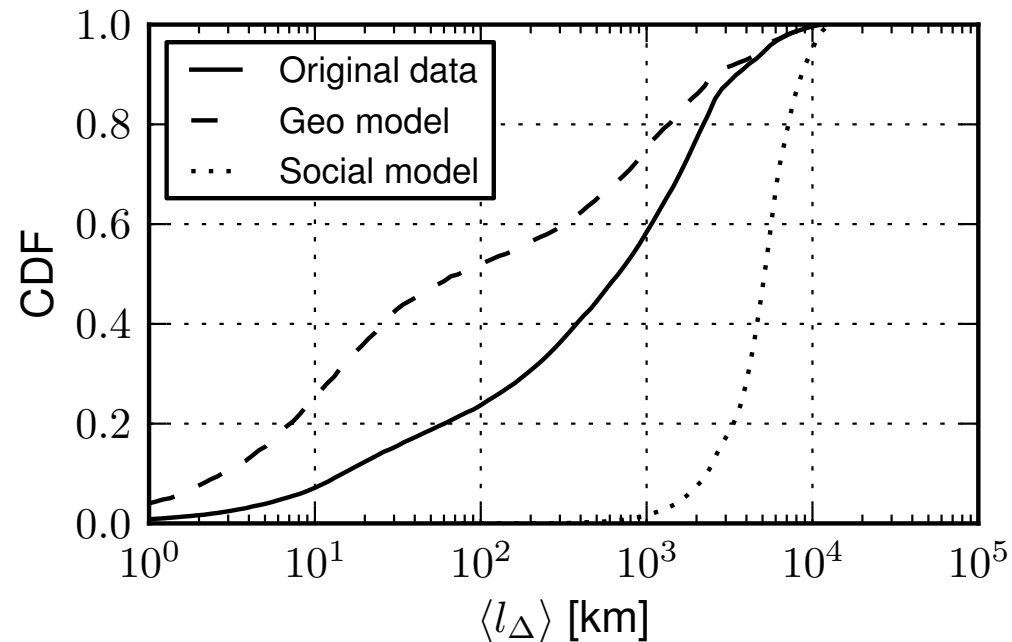
Node neighborhood Γ_i (indicated by an arrow pointing to the summation index)



Average triangle geographic length



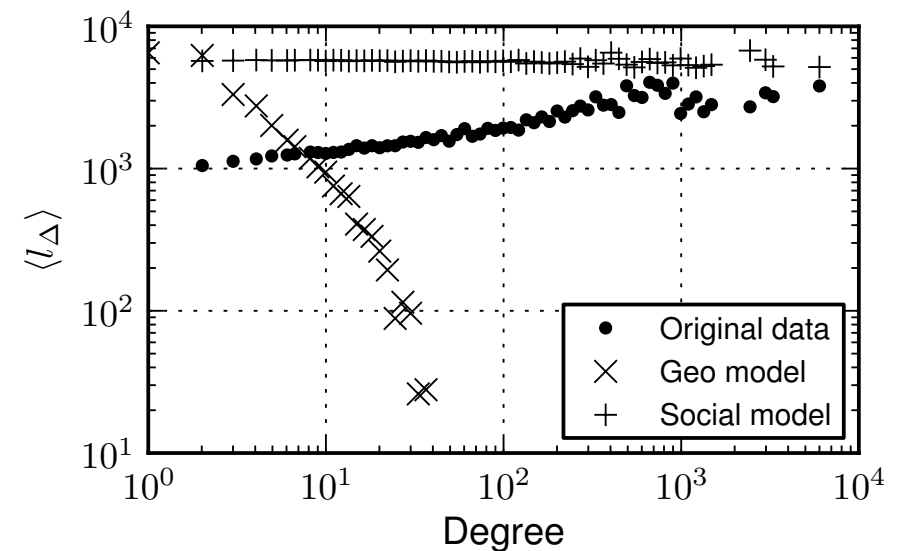
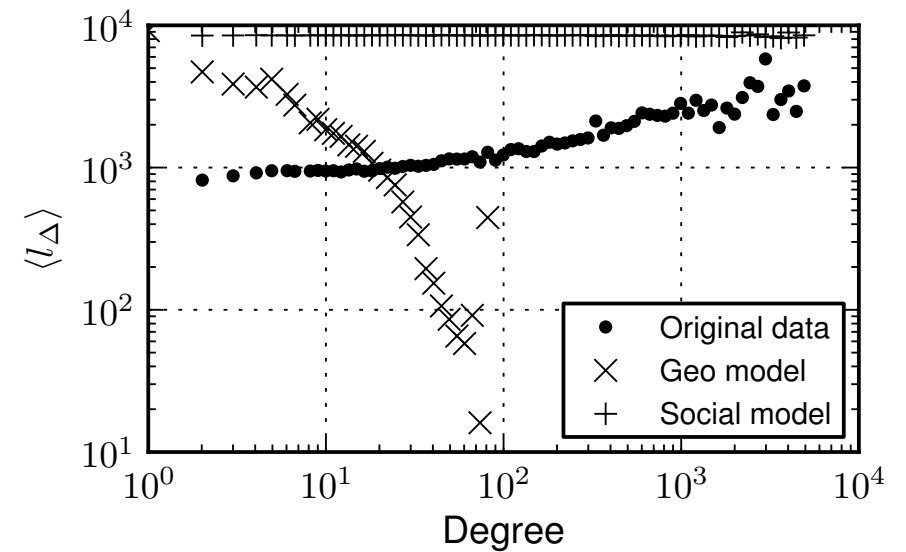
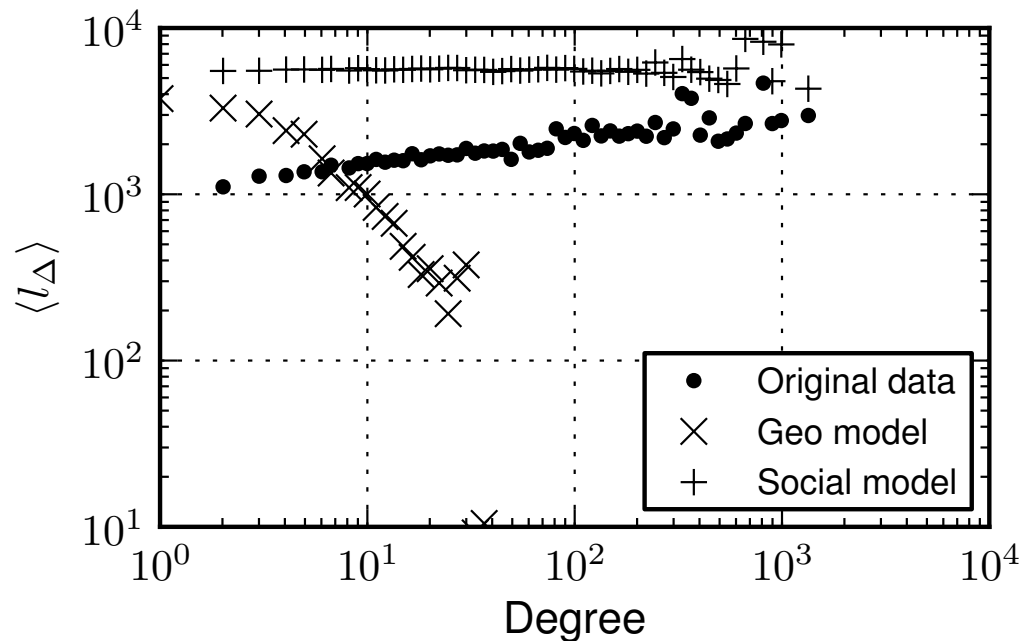
$\langle l_{\Delta} \rangle$ is the average length of the triangles of a user



Correlation triangle length/degree



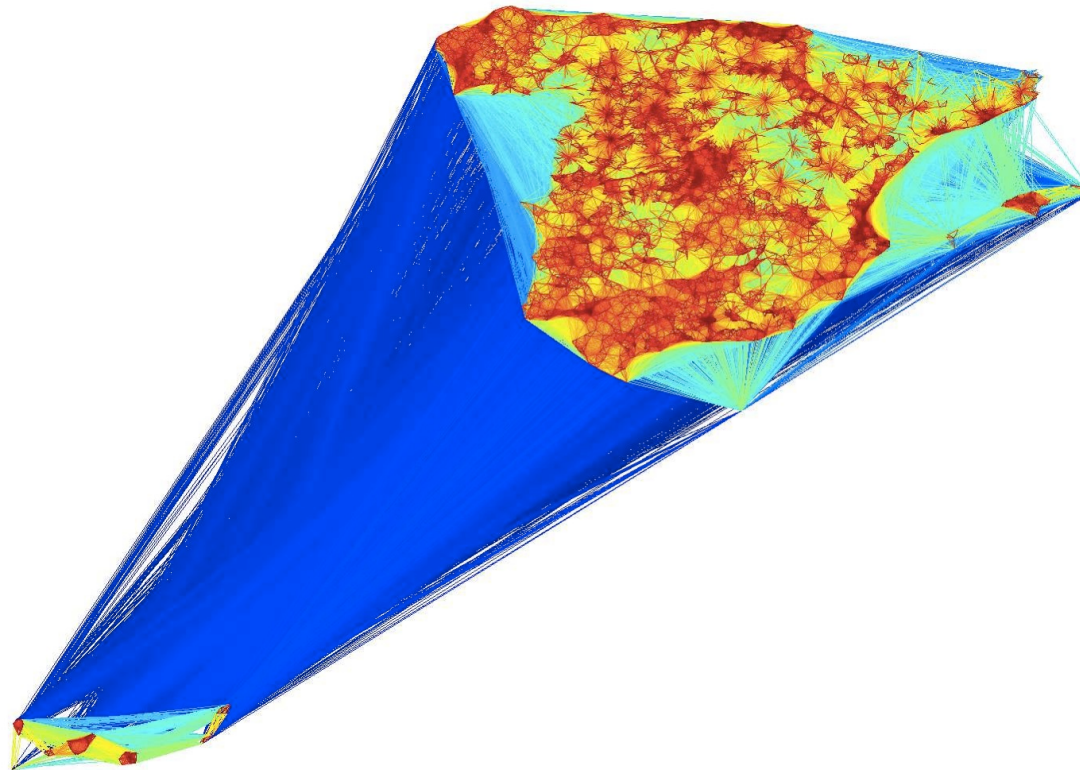
Correlation with
degree: users with
many friends belong
to bigger triangles



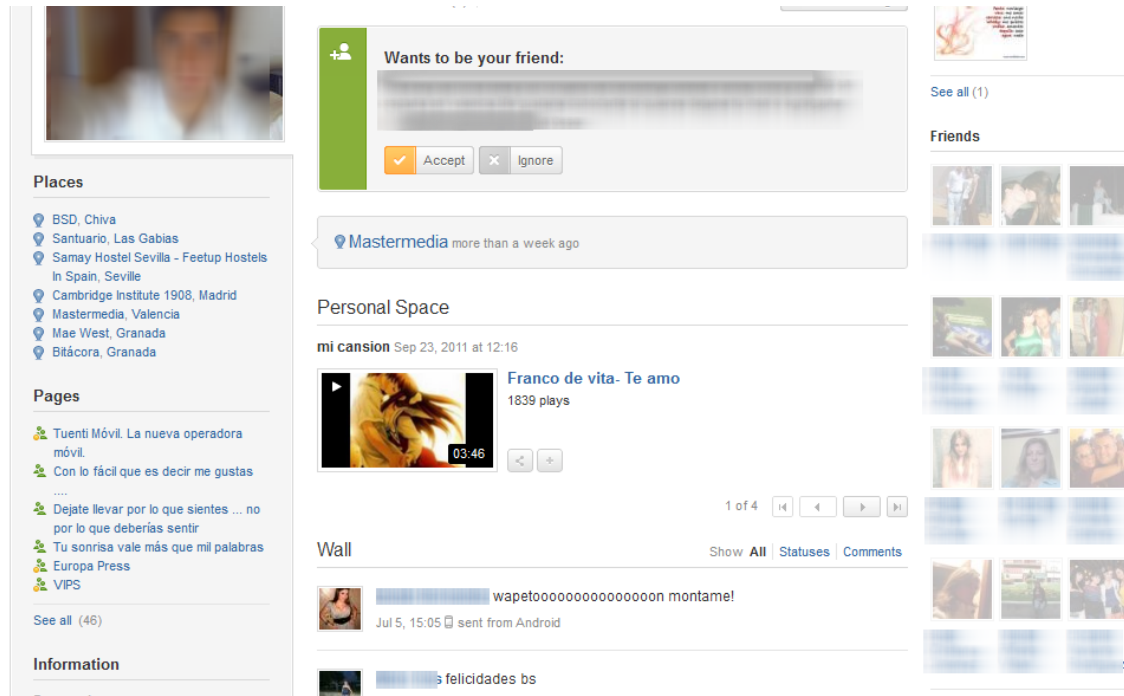


Effect of geography over interaction

How does geography affect interaction?



Tuenti



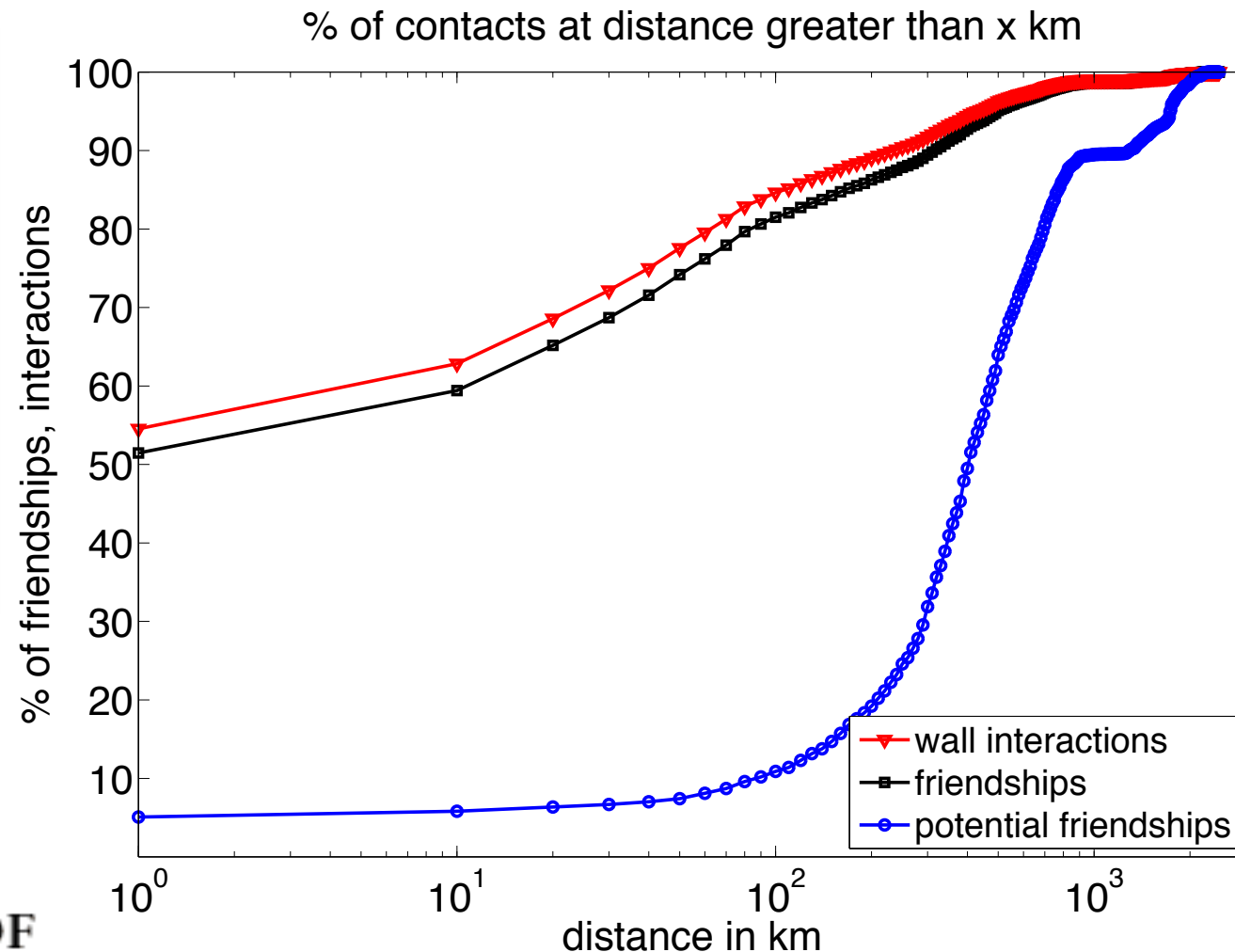
- Tuenti dataset (Nov 11)
- 9.88 million registered users
- ~1 174 million friendship links
- 500 million messages in 3 months

Geographic Properties



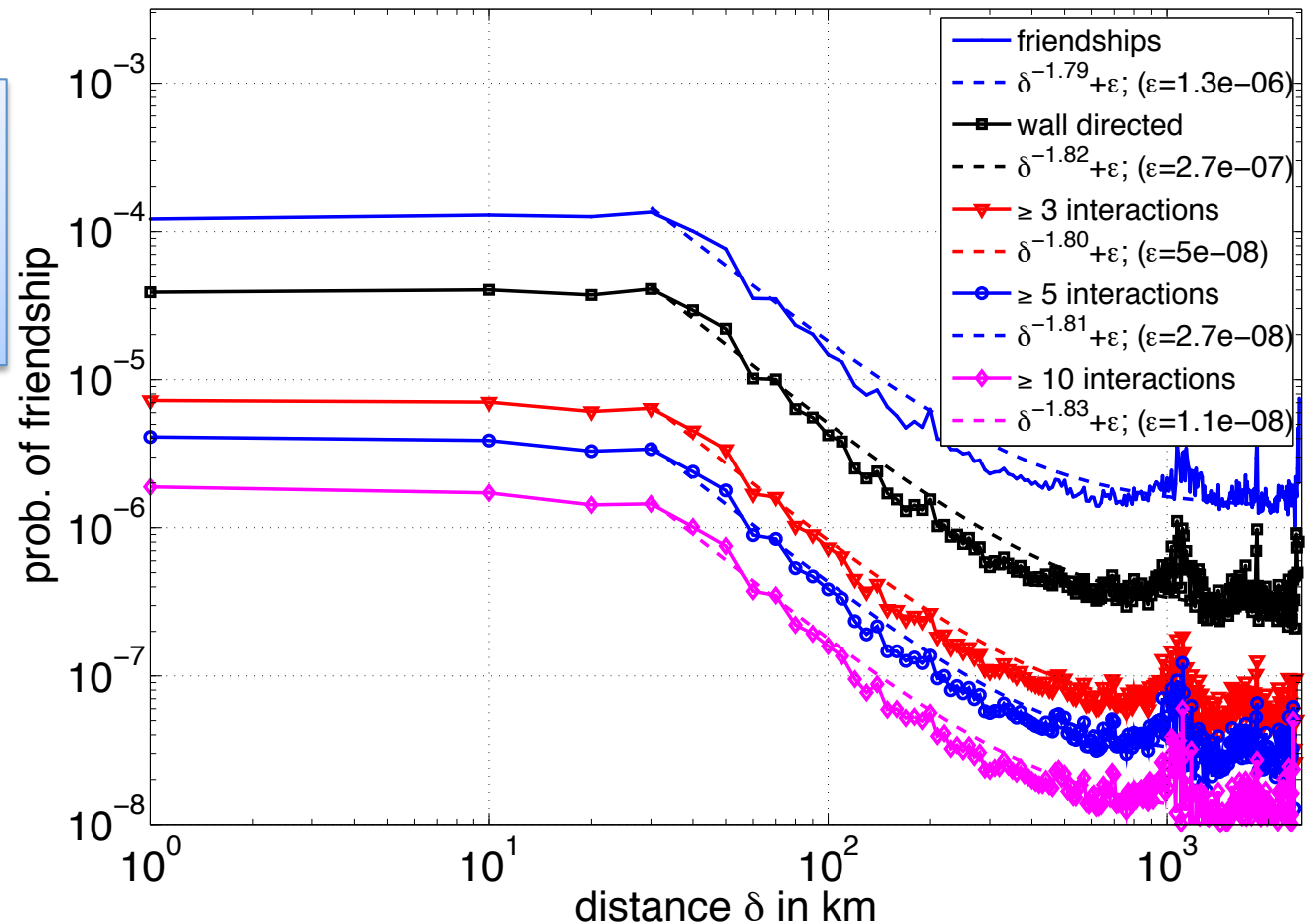
60% of social connections are at a distance of ≤ 10 km.

Only 10% of all distances between users are below 100 km



Effect of geography on friendship

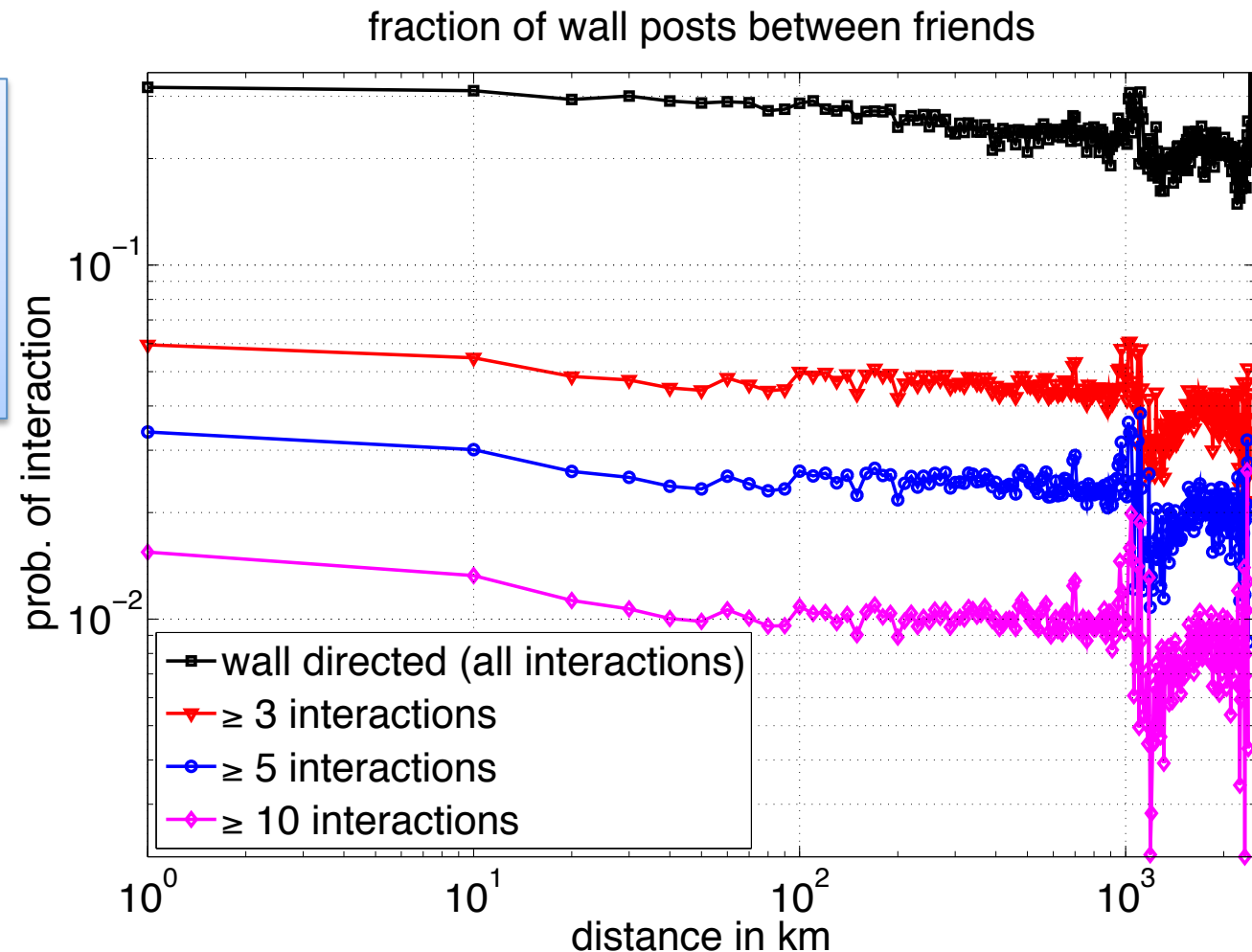
Distance constrains social interaction establishment but has a uniform effect on all interactions



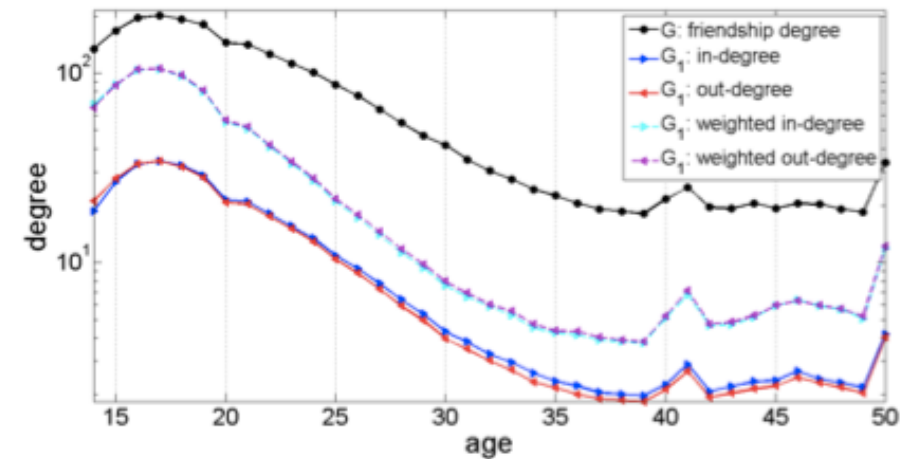
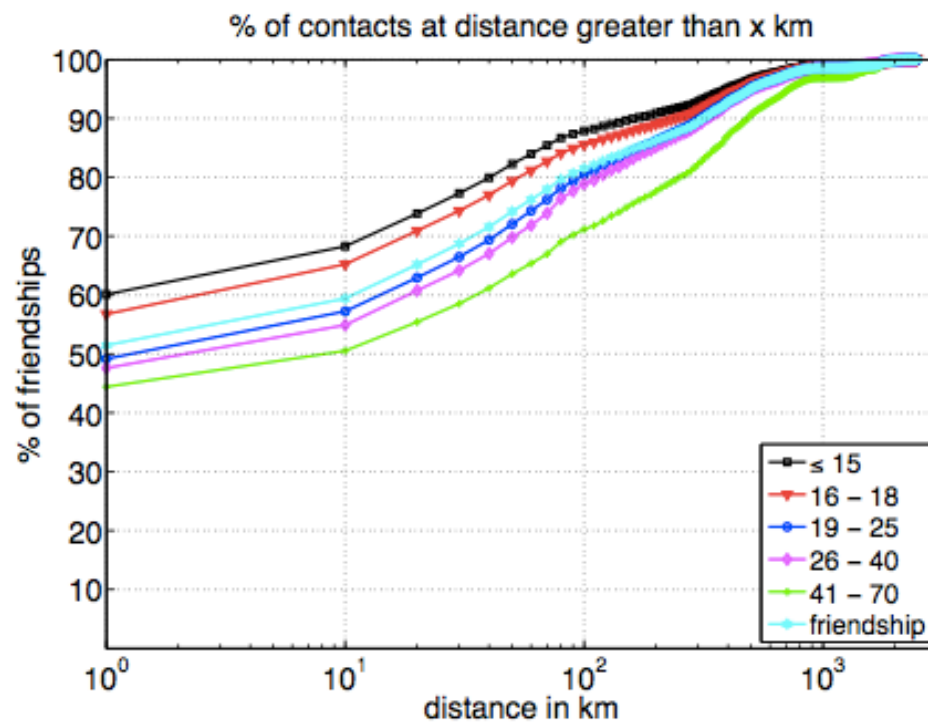
Effects of geography on interactions



Probability that a message is exchanged over a friendship link seems not to be very affected by distance



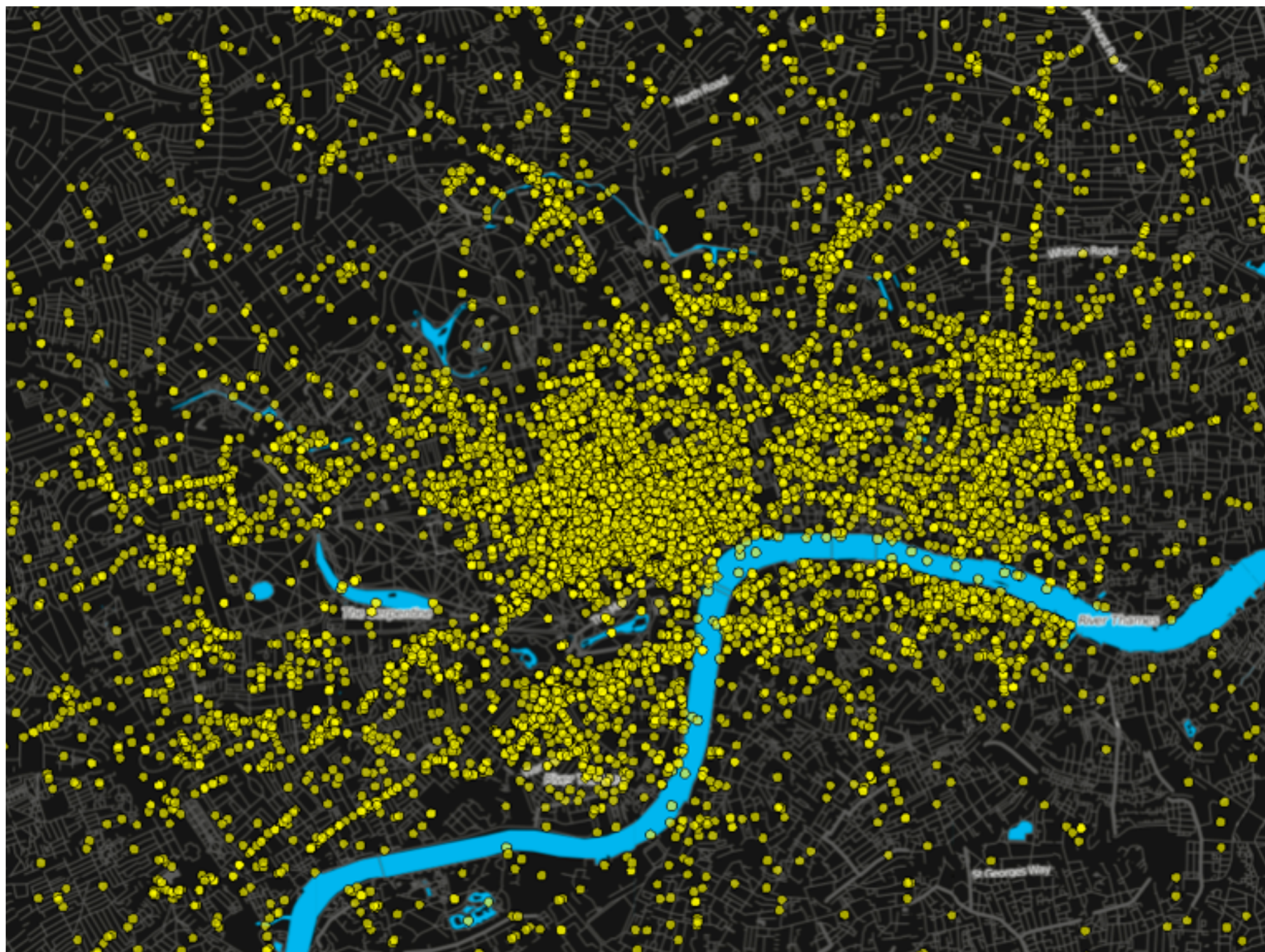
Effect of Age

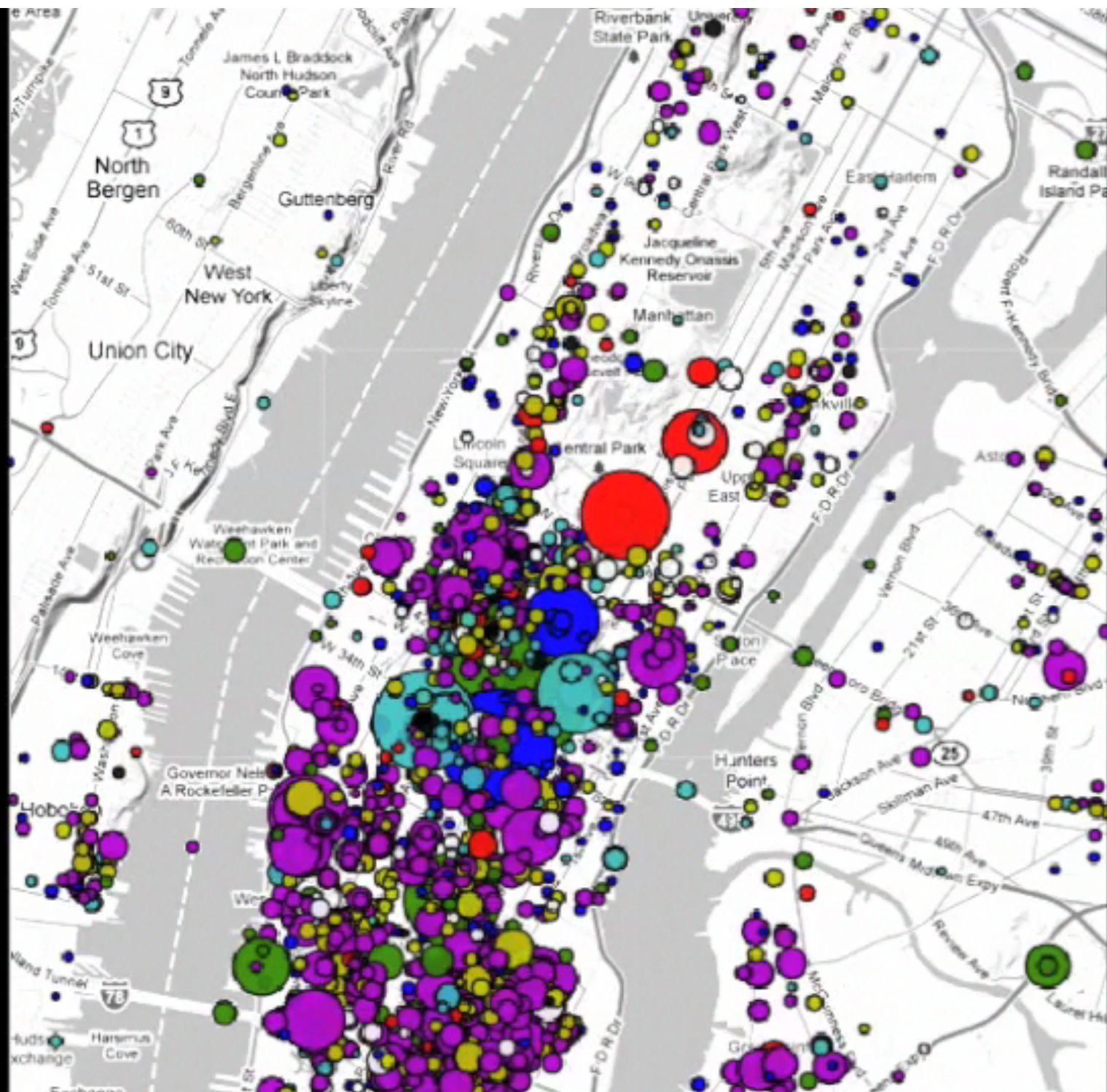


Under 15 have 70% friends within 10km. They also have more friends and interact more.



Understanding human mobility





Samuel A. Stouffer



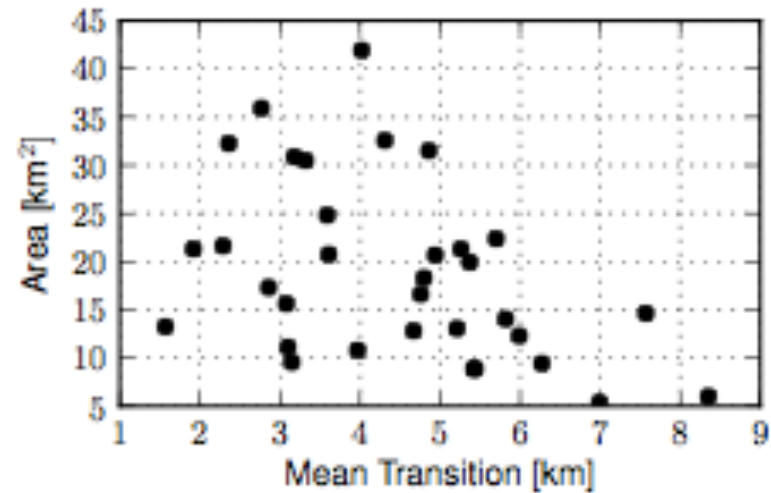
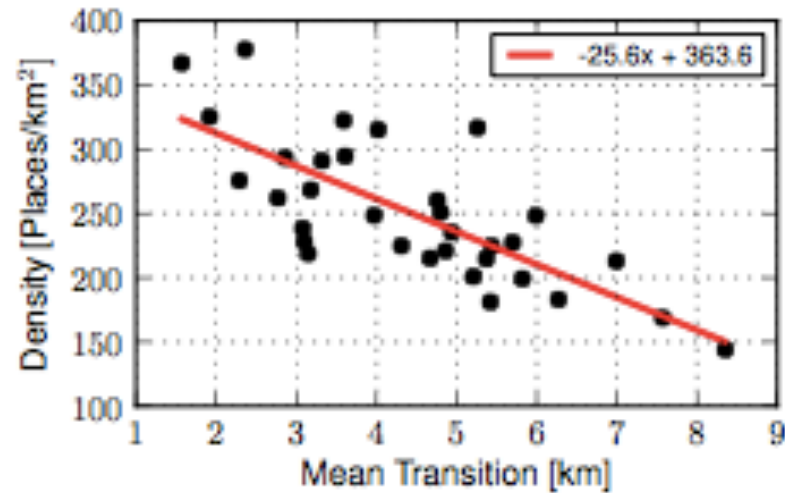
Stouffer's **law of intervening opportunities** states, "*The number of persons going a given distance is directly proportional to the number of opportunities at that distance and inversely proportional to the number of intervening opportunities.*" *

- Empirically proven using data for migrating families in the city of Cleveland.
- Is this true in our data?

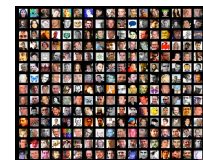
* S. Stouffer (1940) Intervening opportunities: A theory relating mobility and distance, American Sociological Review 5, 845-867



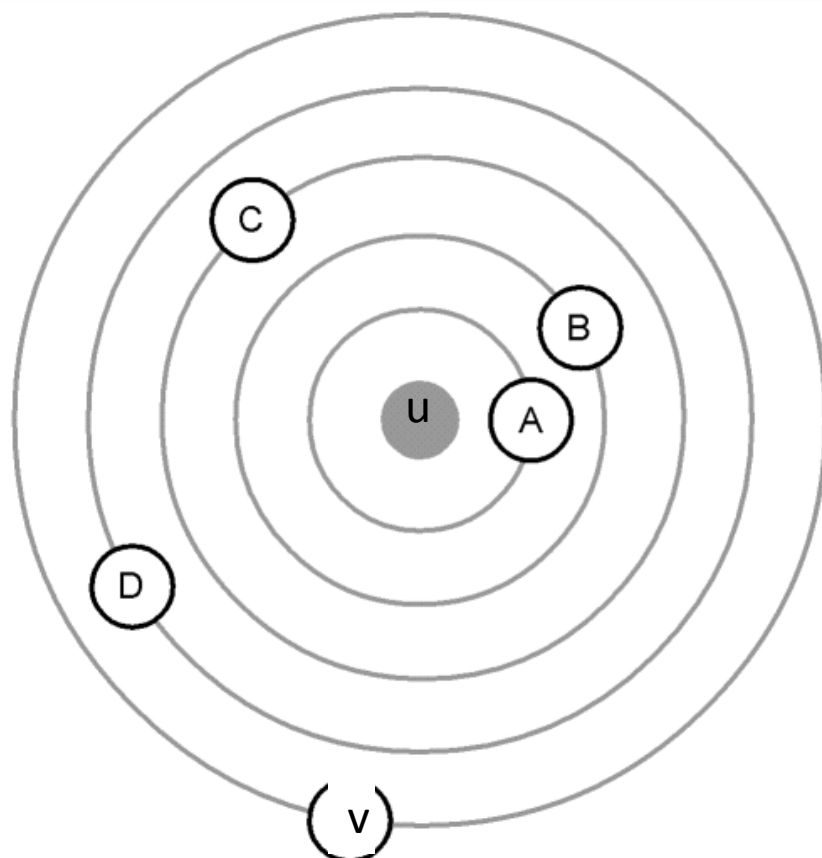
The importance of density



Place density by far more important than city area size with respect to mean length of human movements ($R^2 = 0.59$ and 0.19 respectively).

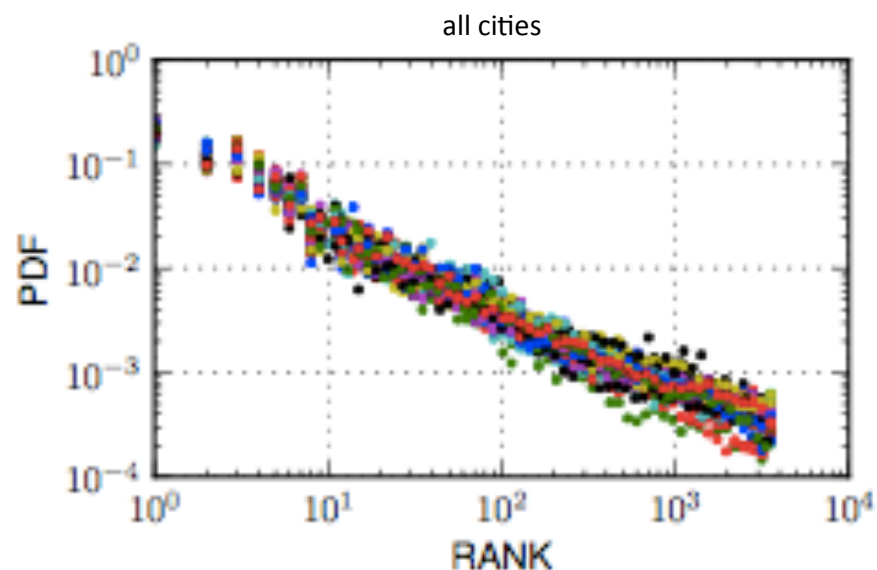
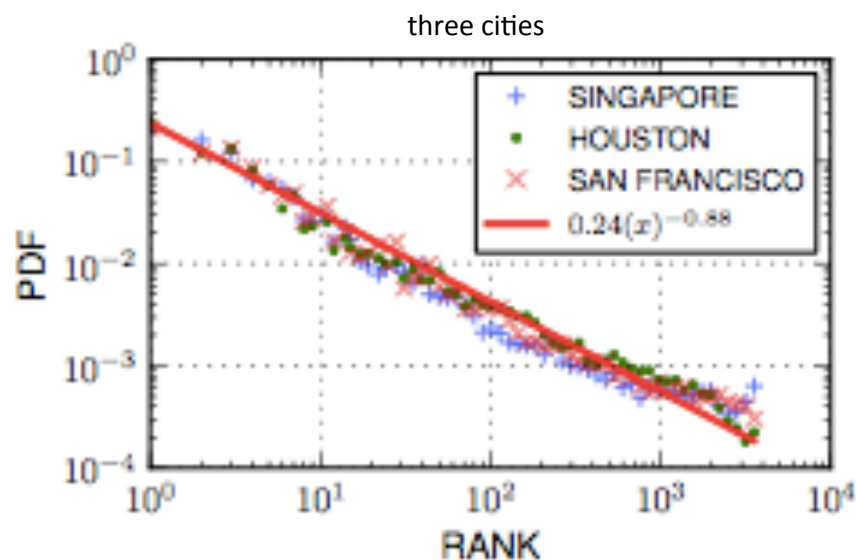


Rank Distance



$$\text{rank}_u(v) = |\{w : d(u, w) < d(u, v)\}|$$

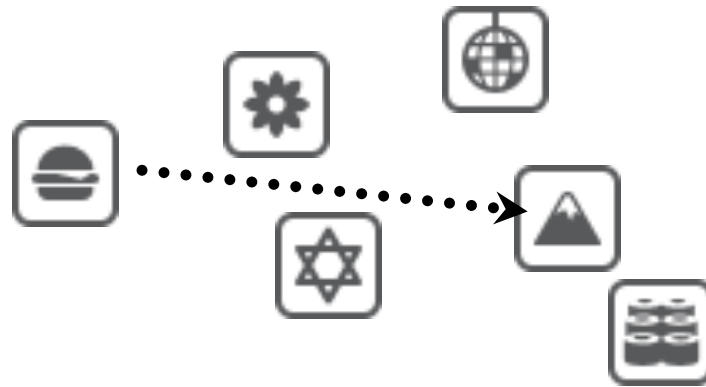
Rank universality



The rank of all cities collapses to a single line.

We have measured a power law exponent $\alpha = 0.84 \pm 0.07$

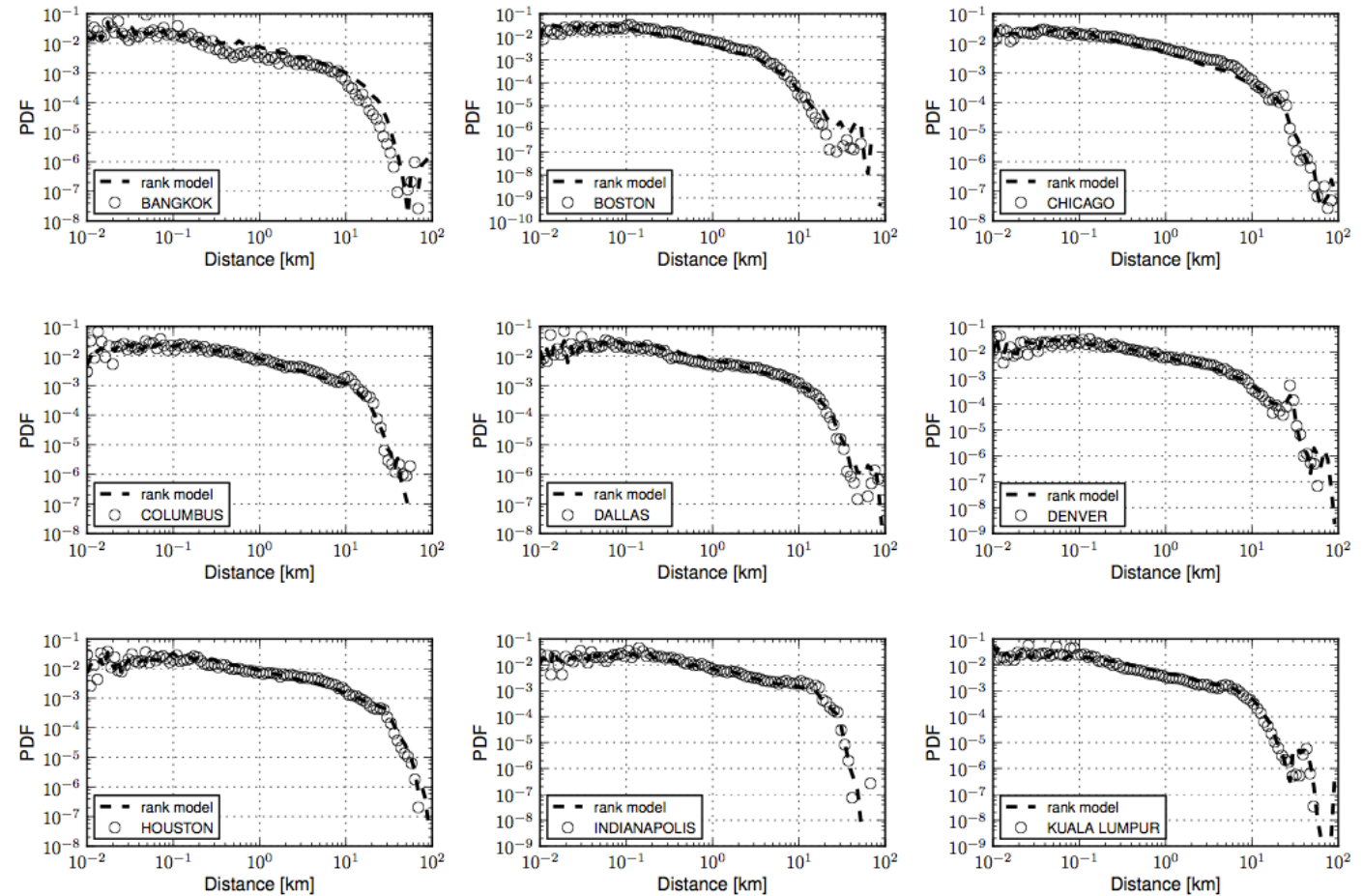
A new model for urban mobility



$$Pr[u \rightarrow v] \propto \frac{1}{rank_u(v)^a}$$



Simulation Results ...





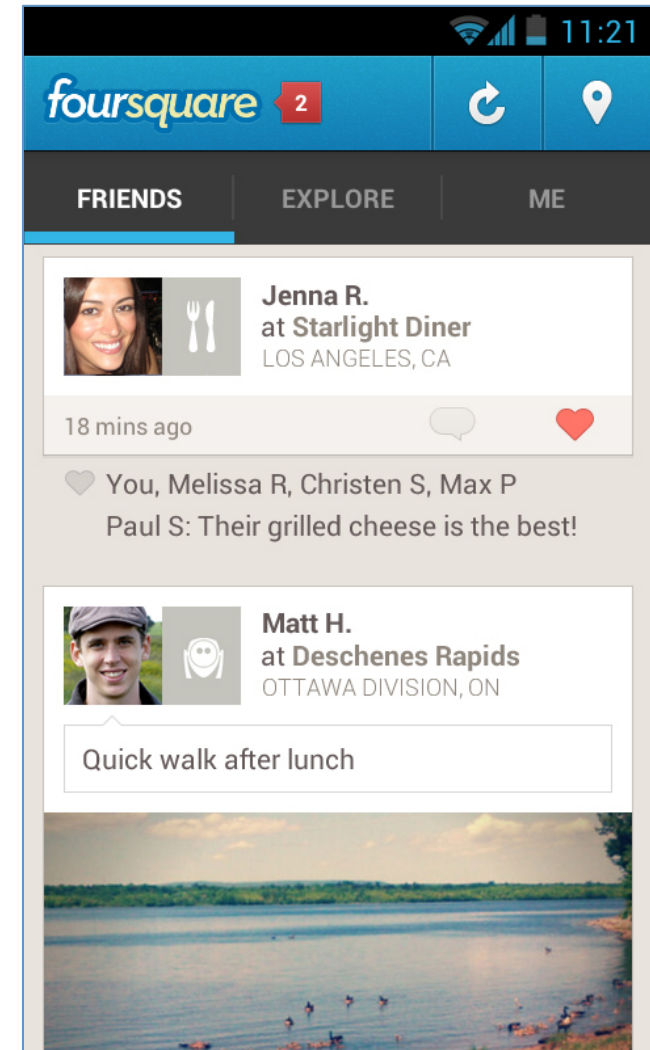
Understanding communities and role of places

City-scale social networks



- We look at **intra-city** social networks
- People who have checked in at a place in a given city, and their friends **who have also checked in** at those places

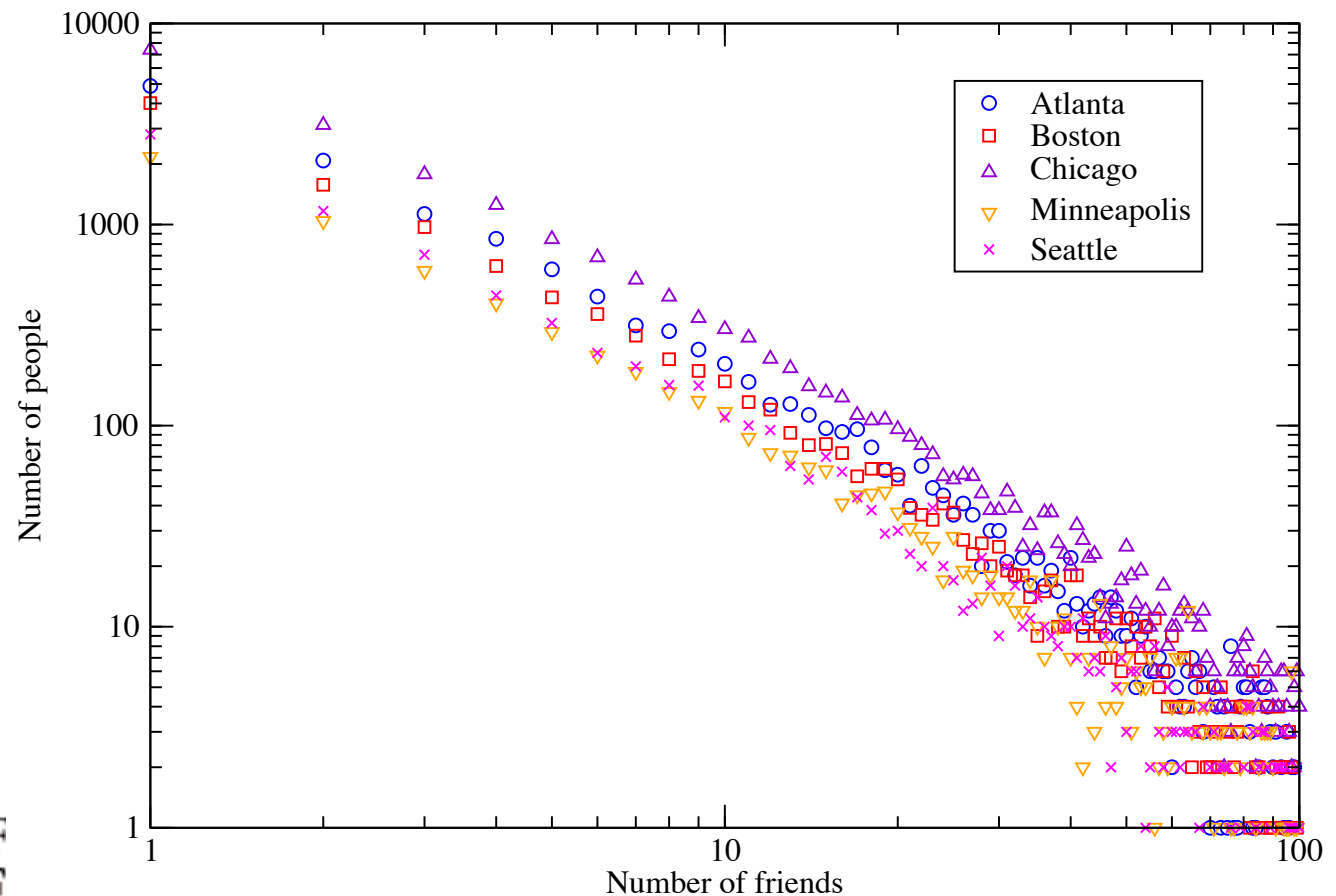
What do these place-based social networks look like?



City-scale social networks



- **Degree:** power-law distribution



City-scale social networks



- **Degree:** power-law distribution
- **Clustering coefficient:** high (between 0.1 and 0.2, in random graph of the same size < 0.001)
- **Average shortest path length:** small (about 4 hops), comparable to random graph (Clustering coeff. + average path length = “small world”)
- **Community structure** (modularity > 0.4)

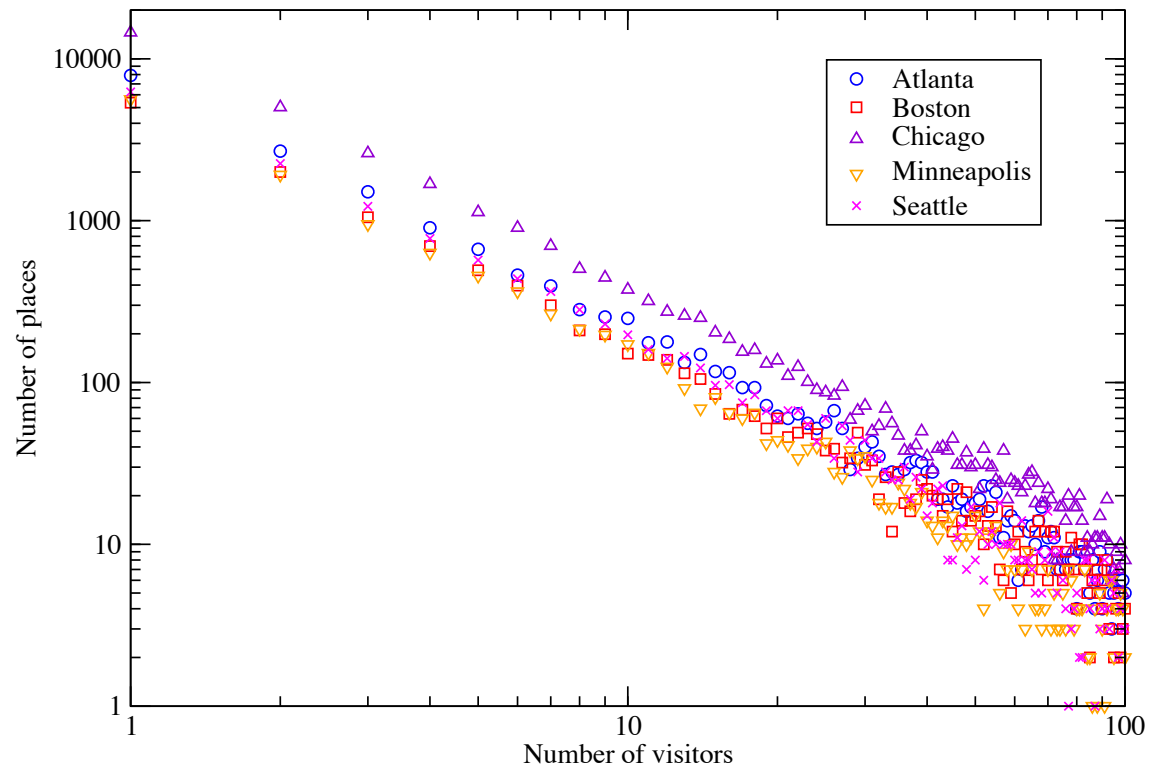
Our city-level graphs have well-known structural properties of social networks.

The role of places



- Power-law distribution of **place popularity**

...like the degree distribution in the social network



Places vital for tie formation



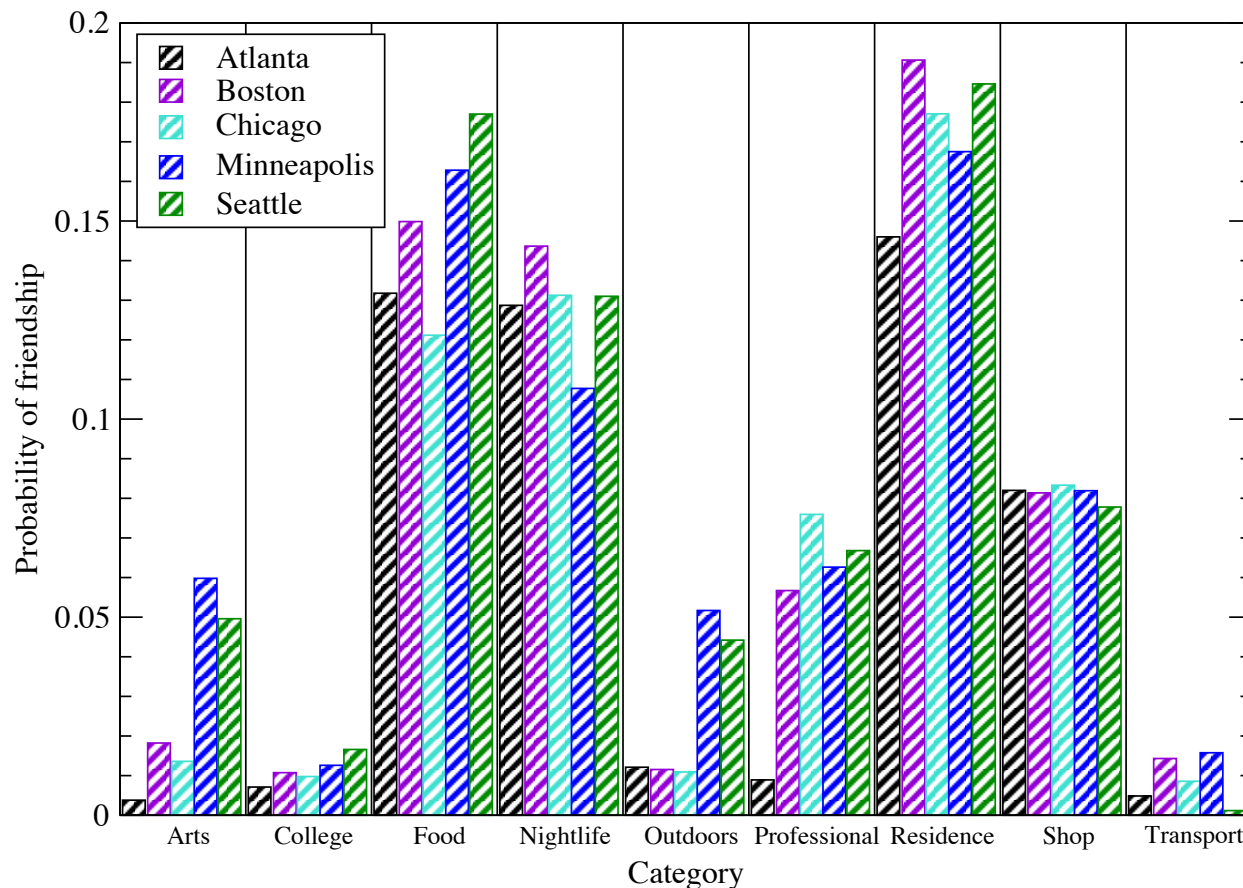
- Power-law distribution of **place popularity**
- **Analyze triangles:** >70% of triangles have one place shared between all three people
→ **clustering around certain places**

These places could act as foci for tie formation...

Role of categories...



- What is the role of place categories?



- Probability of friendship between **colocated people** at places in each Foursquare **category**
- Some kinds of places are **much more likely to reinforce friendship** than others

What can all this be used for?



- **Friendship Recommendation:**
 - **Exploiting Place Features in Link Prediction on Location-based Social Networks**, Salvatore Scellato, Anastasios Noulas, Cecilia Mascolo. In Proceedings of 17th ACM International Conference on Knowledge Discovery and Data Mining (KDD 2011). San Diego, USA. August 2011.
- **Place Recommendation:**
 - **Mining User Mobility Features for Next Place Prediction in Location-based Services**. Anastasios Noulas, Salvatore Scellato, Neal Lathia and Cecilia Mascolo. In Proceedings of IEEE International Conference on Data Mining (ICDM 2012). Short Paper. Brussels, Belgium. December 2012.
 - **A Random Walk Around the City: New Venue Recommendation in Location-Based Social Networks**. Anastasios Noulas, Salvatore Scellato, Neal Lathia and Cecilia Mascolo. In Proceedings of ASE/IEEE International Conference on Social Computing (SocialCom). Amsterdam, The Netherlands. September 2012.

What can all this used for?



- **More Modelling:**
 - **Talking Places: Modelling and Analysing Linguistic Content in Foursquare.** Sandro Bauer, Anastasios Noulas, Diarmuid Ó Séaghdha, Stephen Clark and Cecilia Mascolo. In Proceedings of ASE/IEEE International Conference on Social Computing (SocialCom). Amsterdam, The Netherlands. September 2012.
 - **Exploiting Foursquare and Cellular Data to Infer User Activity in Urban Environments.** Anastasios Noulas, Cecilia Mascolo and Enrique Frias-Martinez. In Proceedings of 14th International Conference on Mobile Data Management (MDM 2013). Milan, Italy. June 2013.
 - **Evolution of a Location-based Online Social Network: Analysis and Models.** Miliadiadis Allamanis, Salvatore Scellato and Cecilia Mascolo. In Proceedings of ACM Internet Measurement Conference (IMC 2012). Boston, MA. November 2012.

References



- **The length of bridge ties: structural and geographic properties of online social interactions.** Yana Volkovich, Salvatore Scellato, David Laniado, Cecilia Mascolo and Andreas Kaltenbrunner. In Proceedings of Sixth International AAAI Conference on Weblogs and Social Media (ICWSM 2012). Full Paper. Dublin, Ireland. June 2012.
- **Far from the eyes, close on the Web: impact of geographic distance on online social interactions.** Andreas Kaltenbrunner, Salvatore Scellato, Yana Volkovich, David Laniado, Dave Currie, Erik J. Jutemar, Cecilia Mascolo. In ACM SIGCOMM Workshop on Online Social Networks (WOSN 2012). Helsinki, Finland. August 2012.
- **A tale of many cities: universal patterns in human urban mobility.** Anastasios Noulas, Salvatore Scellato, Renaud Lambiotte, Massimiliano Pontil, Cecilia Mascolo. In PLoS ONE. PLoS ONE 7(5): e37027. doi:10.1371/journal.pone.0037027
- **The Importance of Being Placefriends: Discovering Location-focused Online Communities.** Chloë Brown, Vincenzo Nicosia, Salvatore Scellato, Anastasios Noulas, Cecilia Mascolo. In ACM SIGCOMM Workshop on Online Social Networks (WOSN 2012). Helsinki, Finland. August 2012.