Spatial structure of cities

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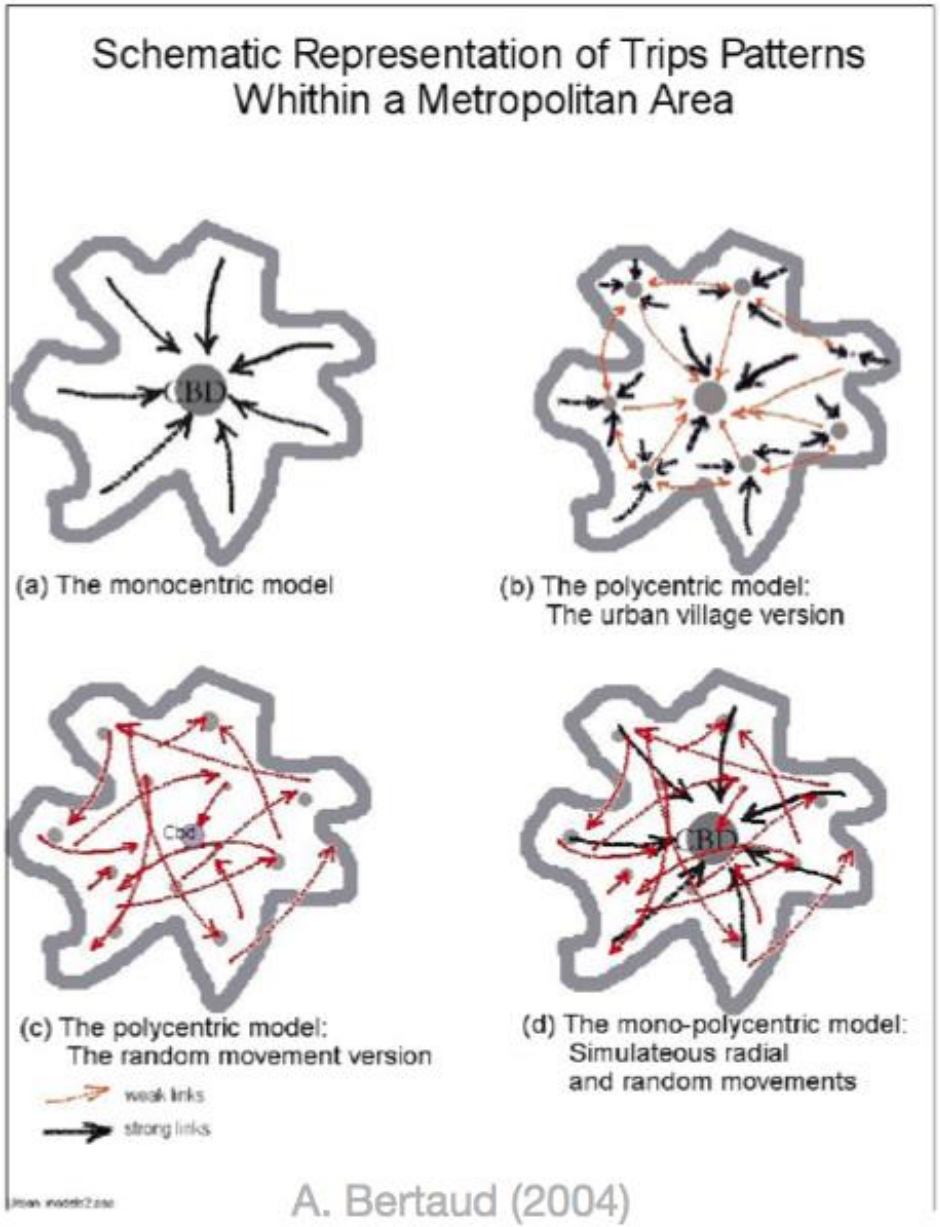
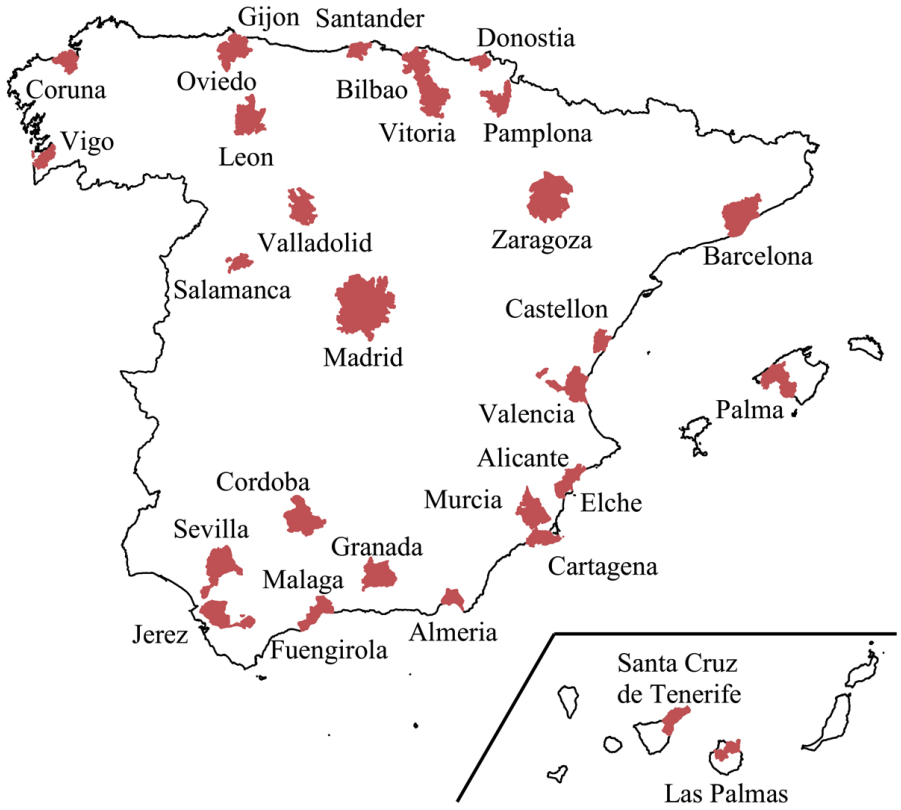
Outline

- **Motivation**
- **Cell phone data**
- **Initial Results**
- **Metrics**
- **Hotspots**
- **Mobility and hotspots**
- **Conclusions**

Motivation

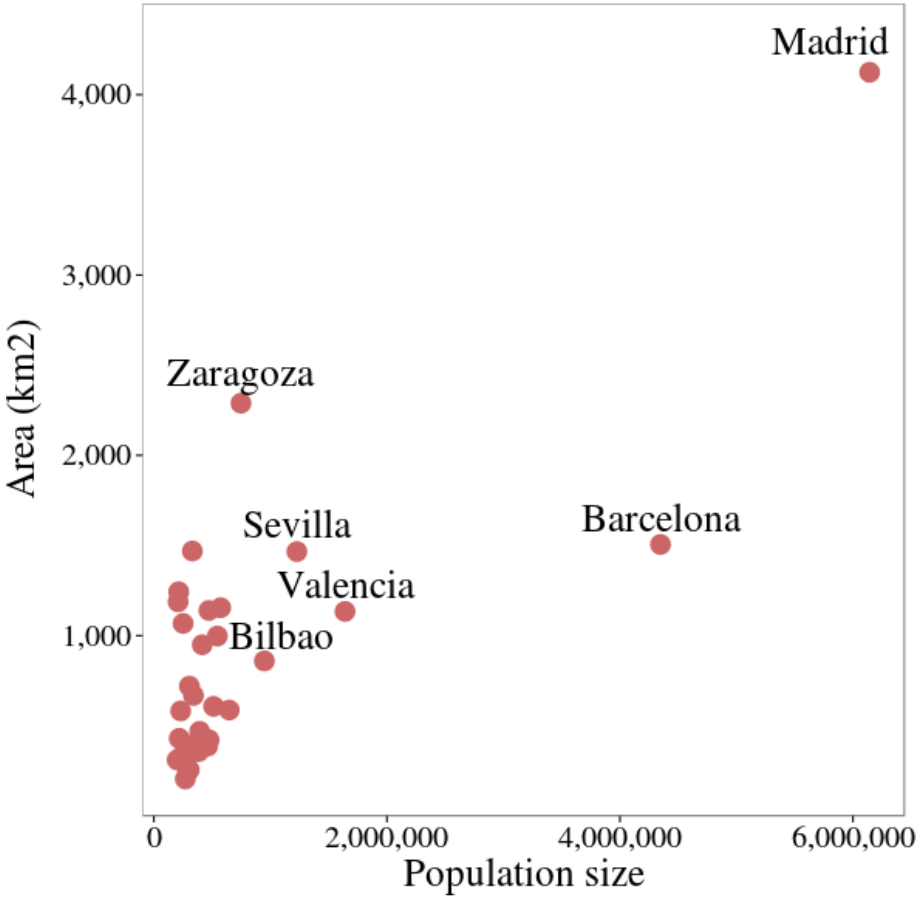

Schematic Representation of Trips Patterns
Whithin a Metropolitan Area
BD
(a) The monocentric model
(b) The polycentric model:
The urban village version
CBD
(c) The polycentric model:
The random movement version
weak links
strong links
BD
(d) The mono-polycentric model:
Simulateous radial
and random movements
A. Bertaud (2004)

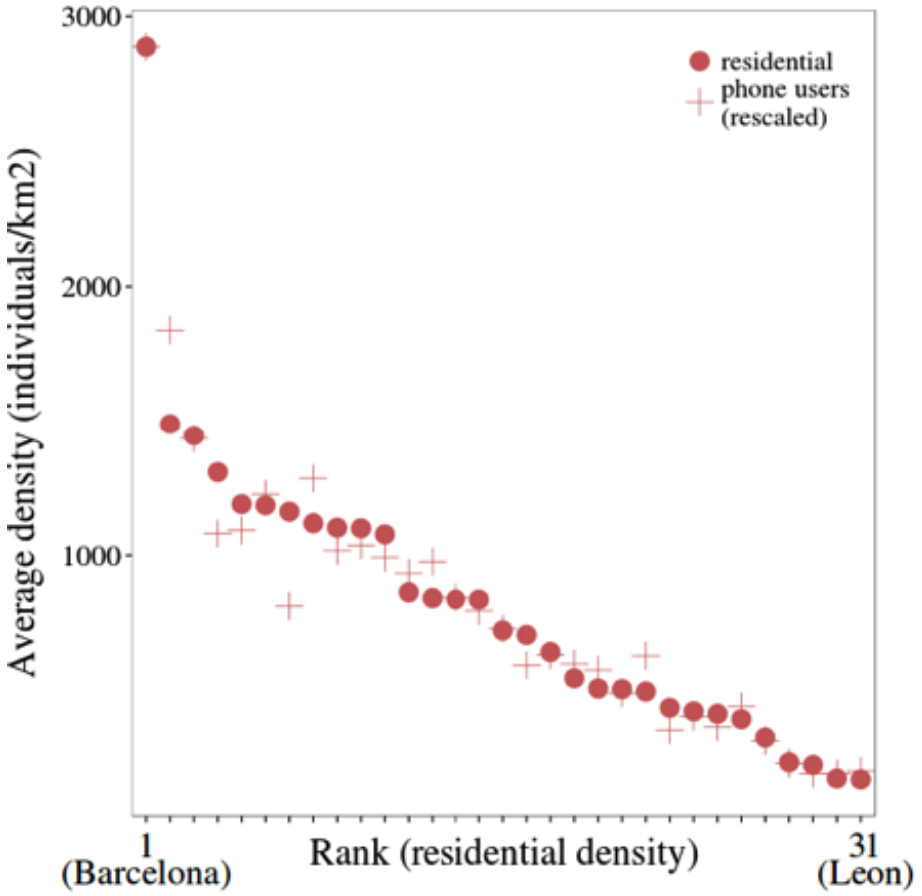
Data



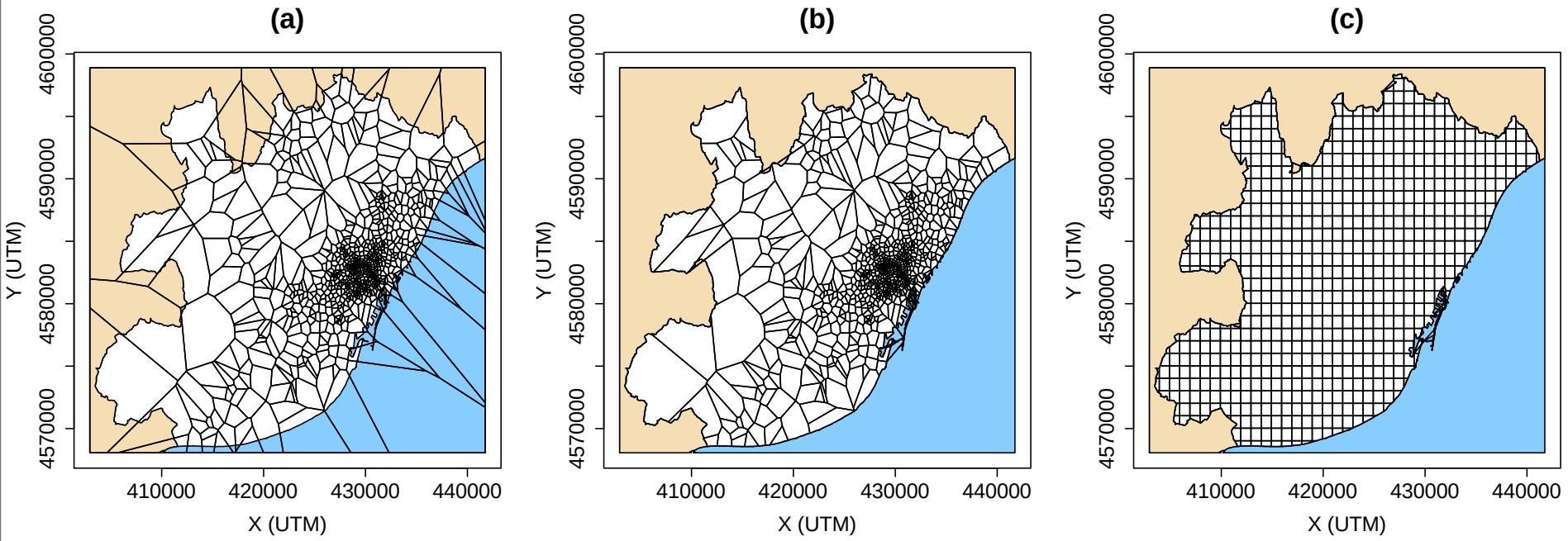
31 urban areas with more than 200,000 inhabitants
55 days in fall 2009
On average 2% population (max 5%).

Data

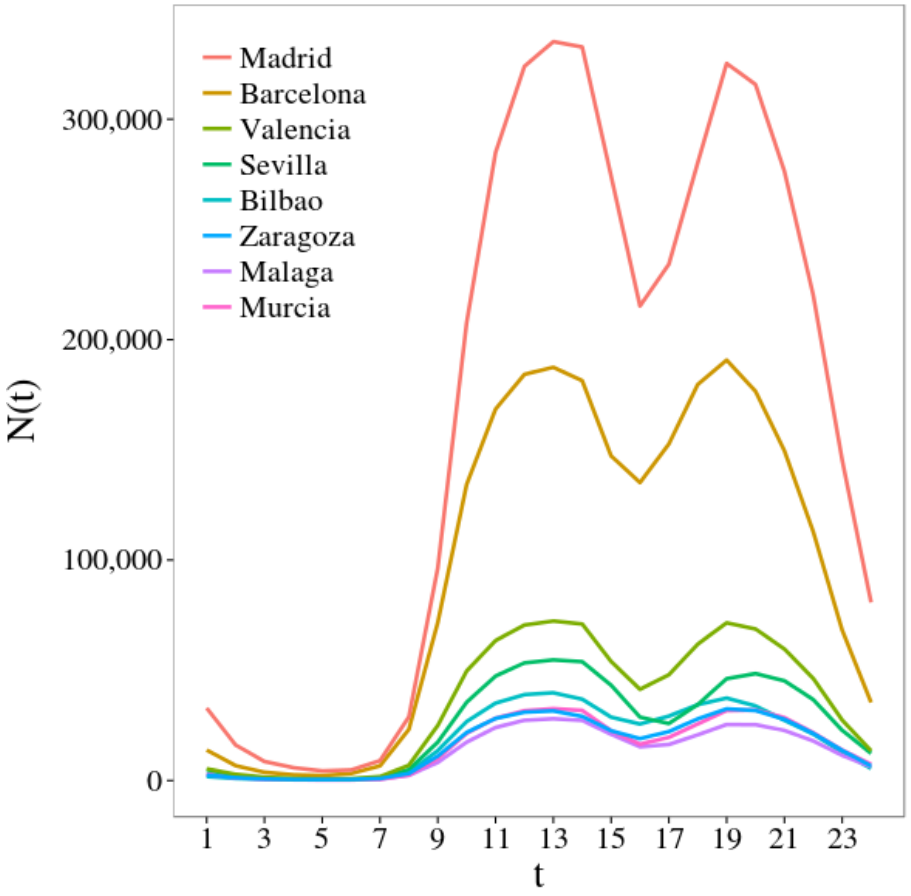

Madrid
Zaragoza
Sevilla
Barcelona
Valencia
Bilbao
4,000
3,000
2,000
1,000
Area (km2)
0
2,000,000
4,000,000
6,000,000
Population size

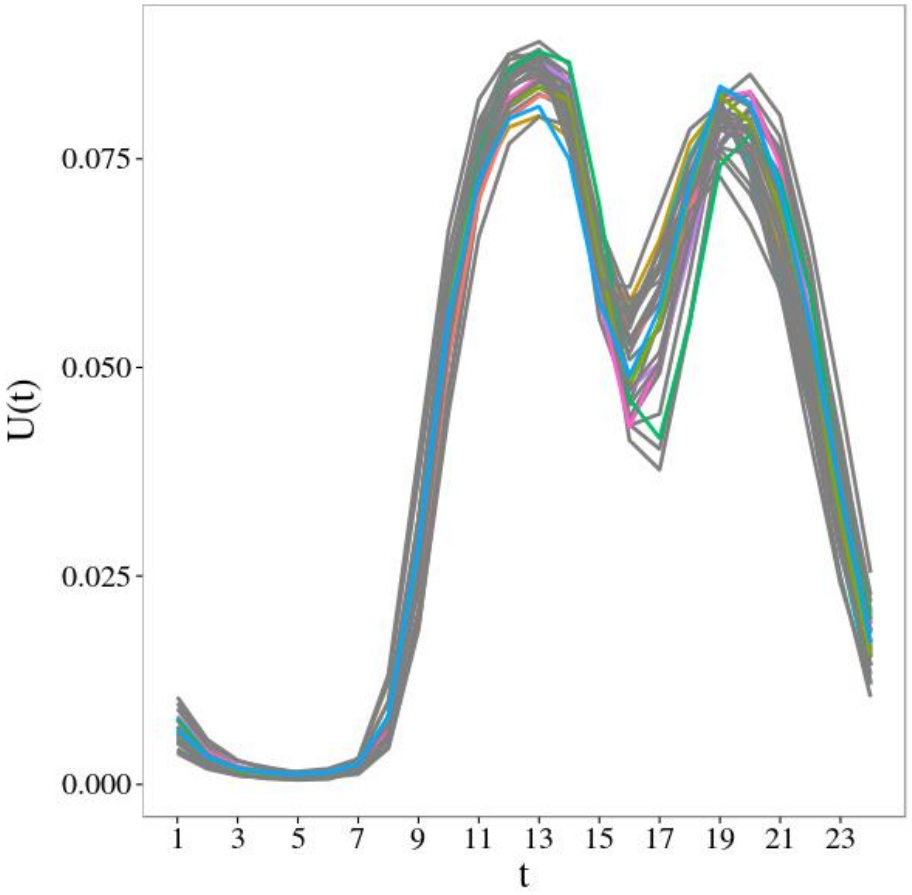

3000
2000
1000
Average density (individuals/km2)
residential
phone users
(rescaled)
1
(Barcelona)
Rank (residential density)
31
(Leon)

Data


(a)
(b)
(c)
Y (UTM)
X (UTM)
4570000
4580000
4590000
4600000
410000
420000
430000
440000

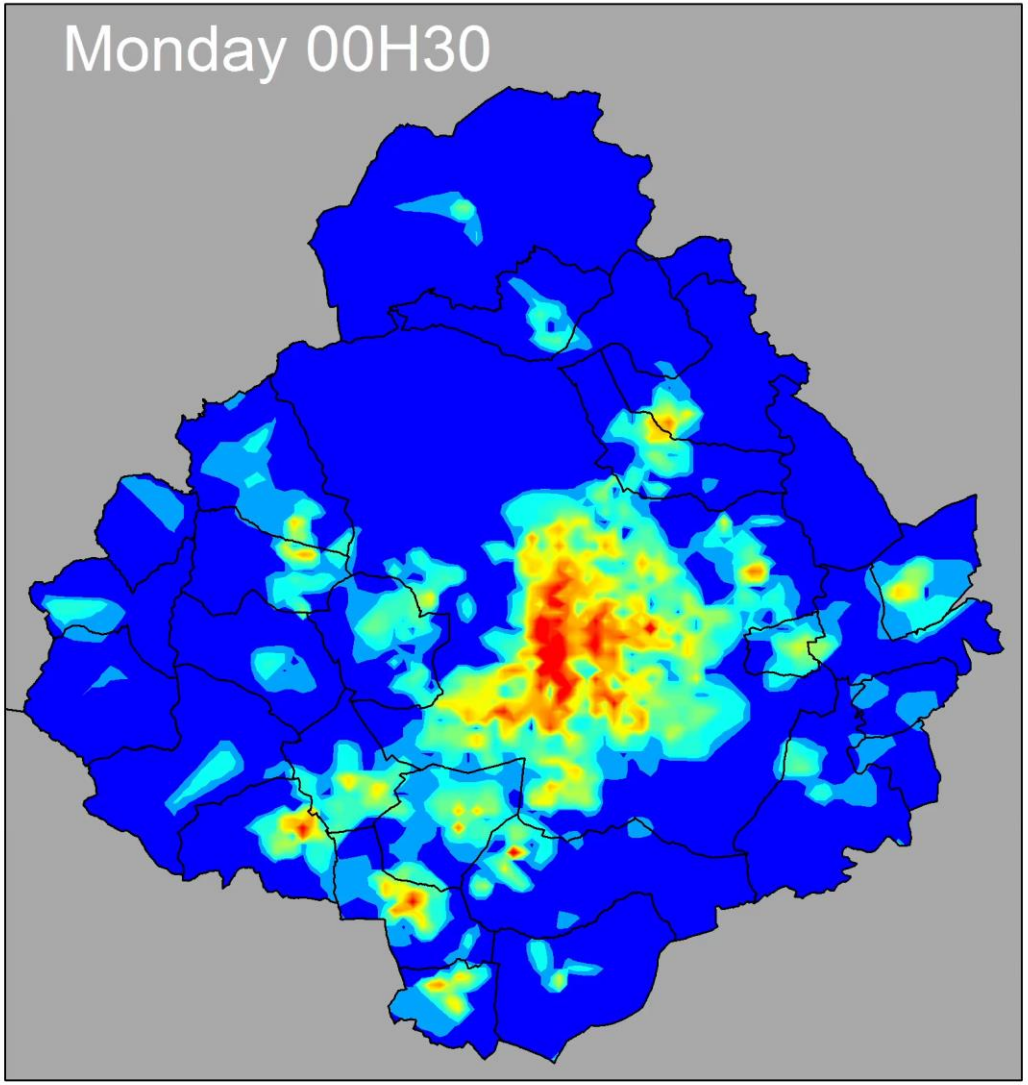
Initial results





Hotspots

Madrid



Metrics

To measure the differences in population concentration along time and across cities, we define two metrics:

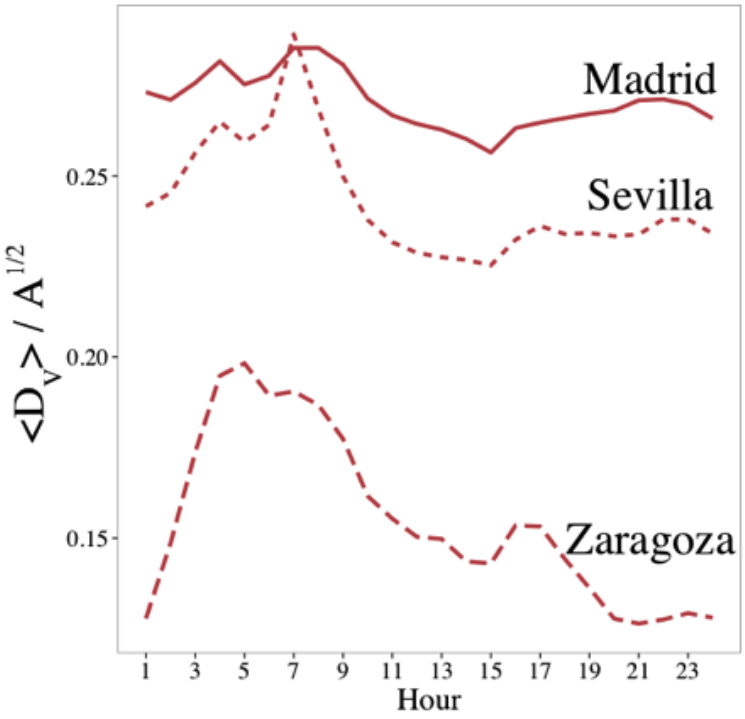
- Average weighted distance:

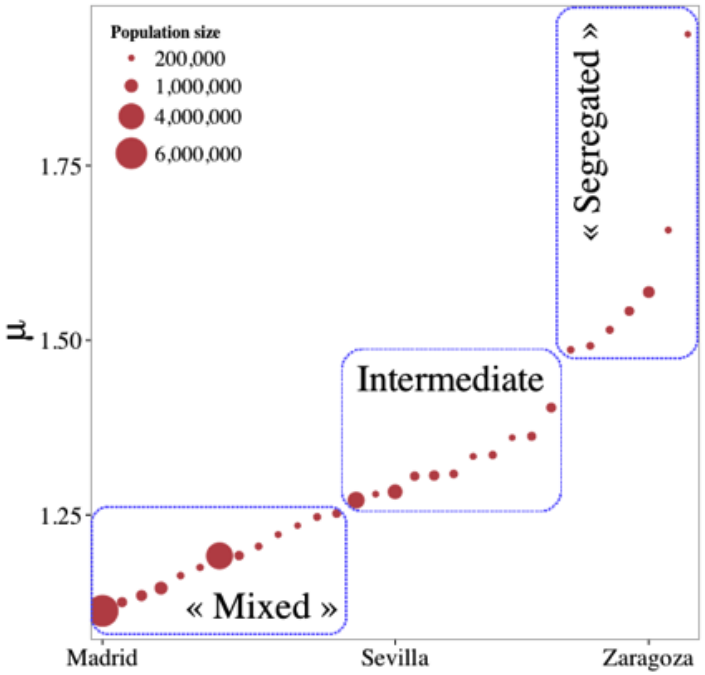
$$D_v = \frac{\sum_{i<j} s_i s_j d_{ij}}{\sum_{i<j} s_i s_j}$$

- Dilation coefficient:

$$m = \frac{\max_t(D_v(t))}{\min_t(D_v(t))}$$

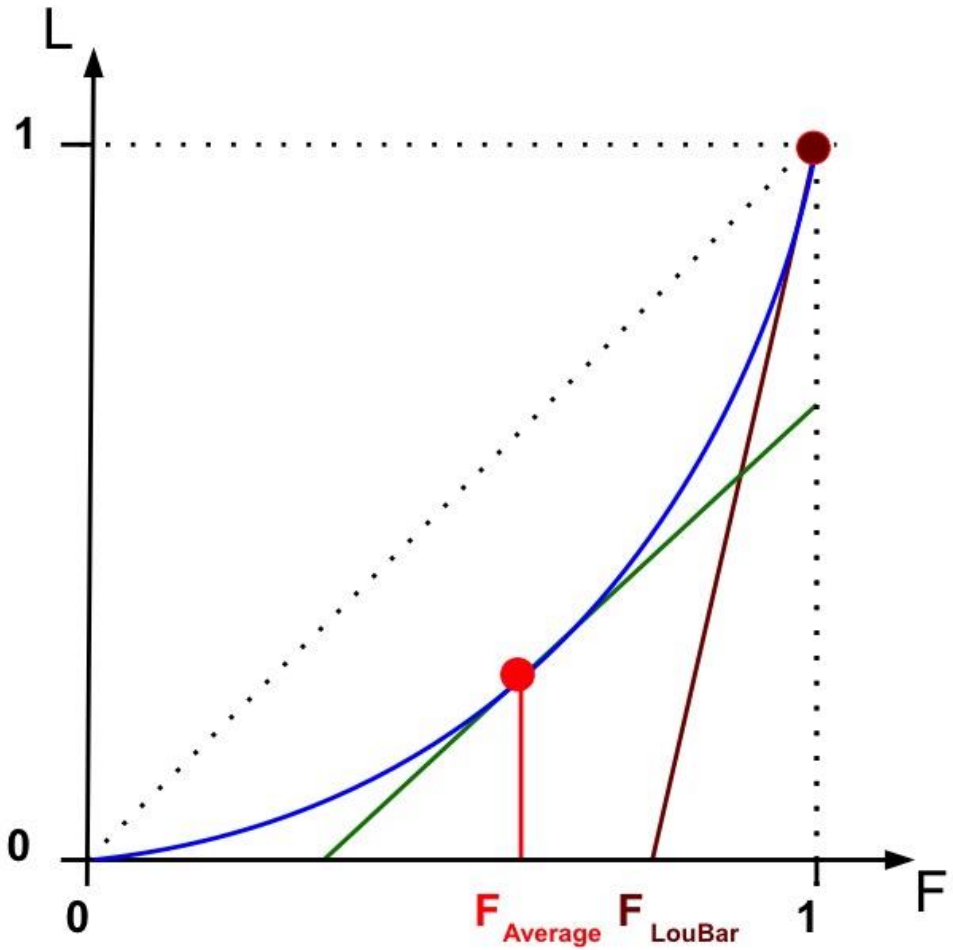
Metrics


Madrid
Sevilla
Zaragoza
0.25
0.20
0.15
1 3 5 7 9 11 13 15 17 19 21 23
Hour
<D_v> / A^1/2

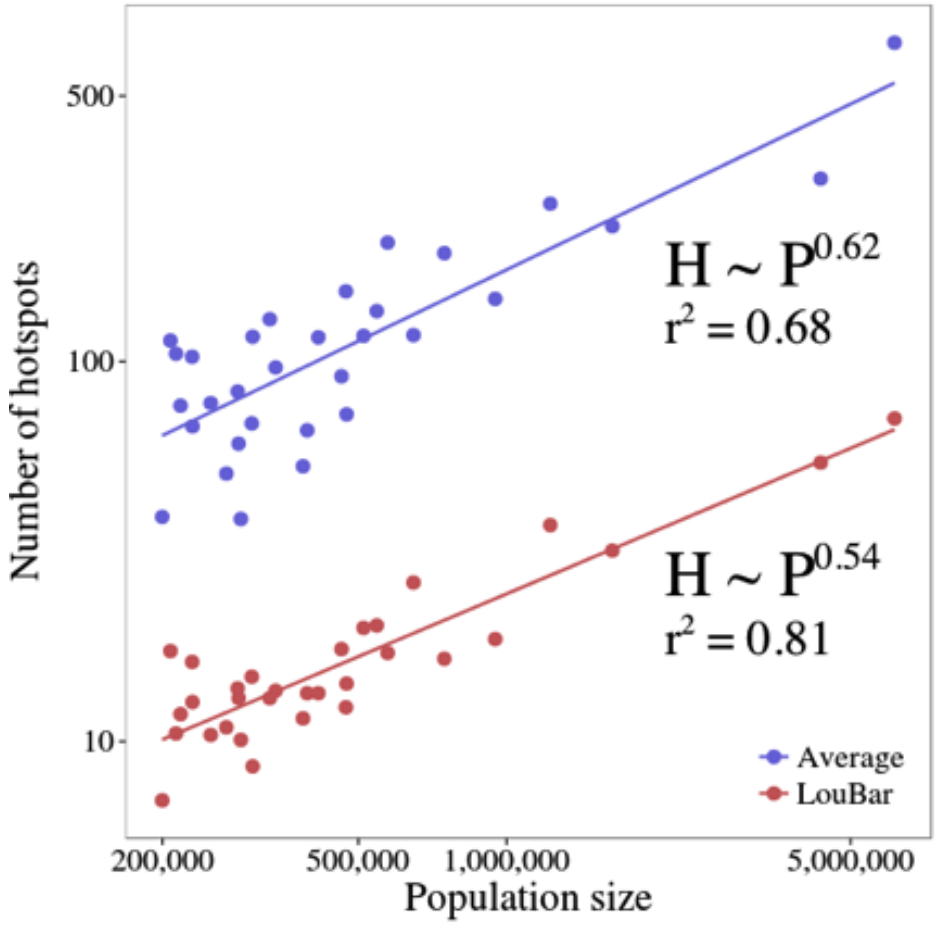

Population size
200,000
1,000,000
4,000,000
6,000,000
« Segregated »
Intermediate
« Mixed »
1.75
1.50
1.25
μ
Madrid
Sevilla
Zaragoza

Hotspots

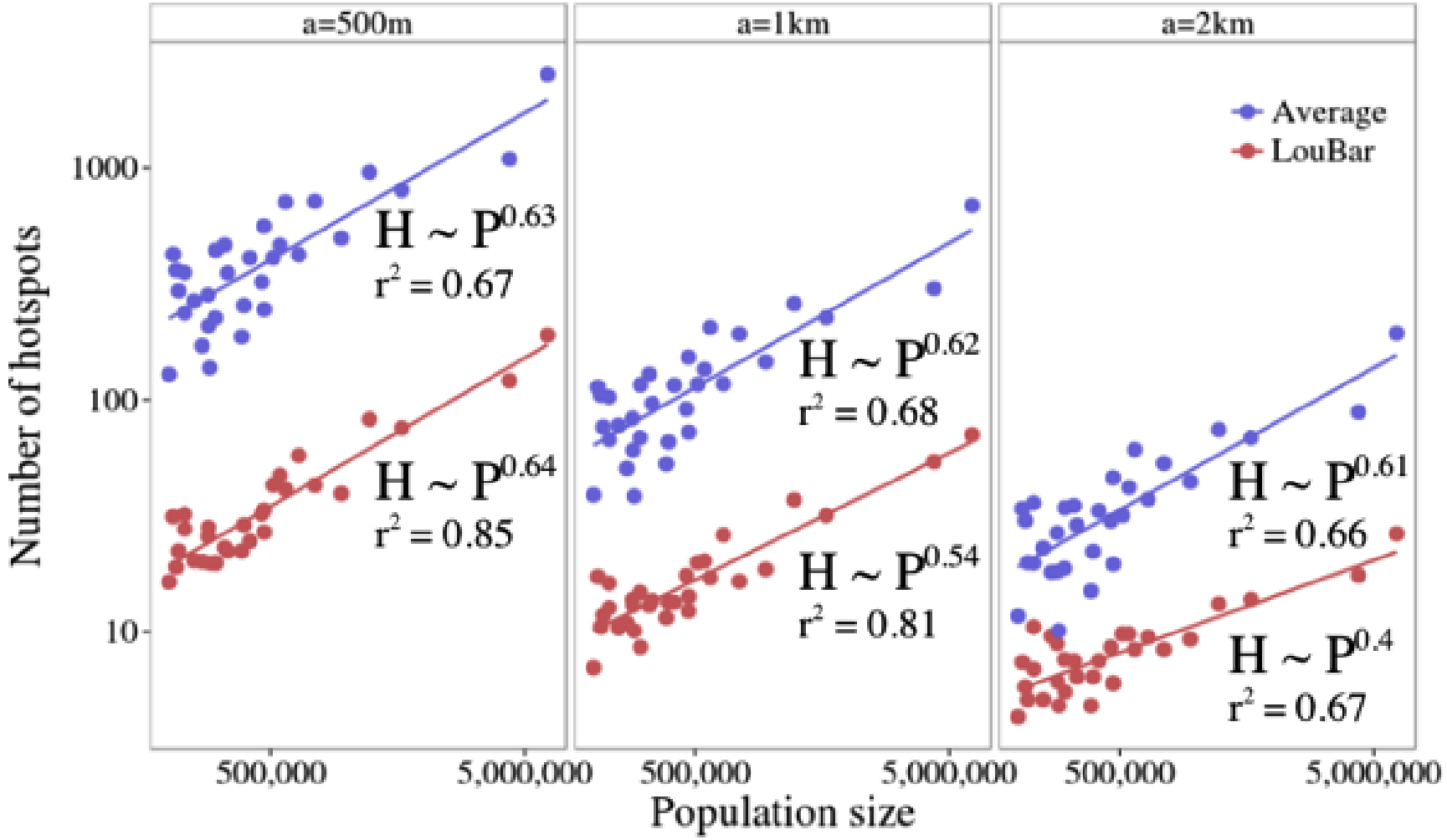
Definition of hotspots:



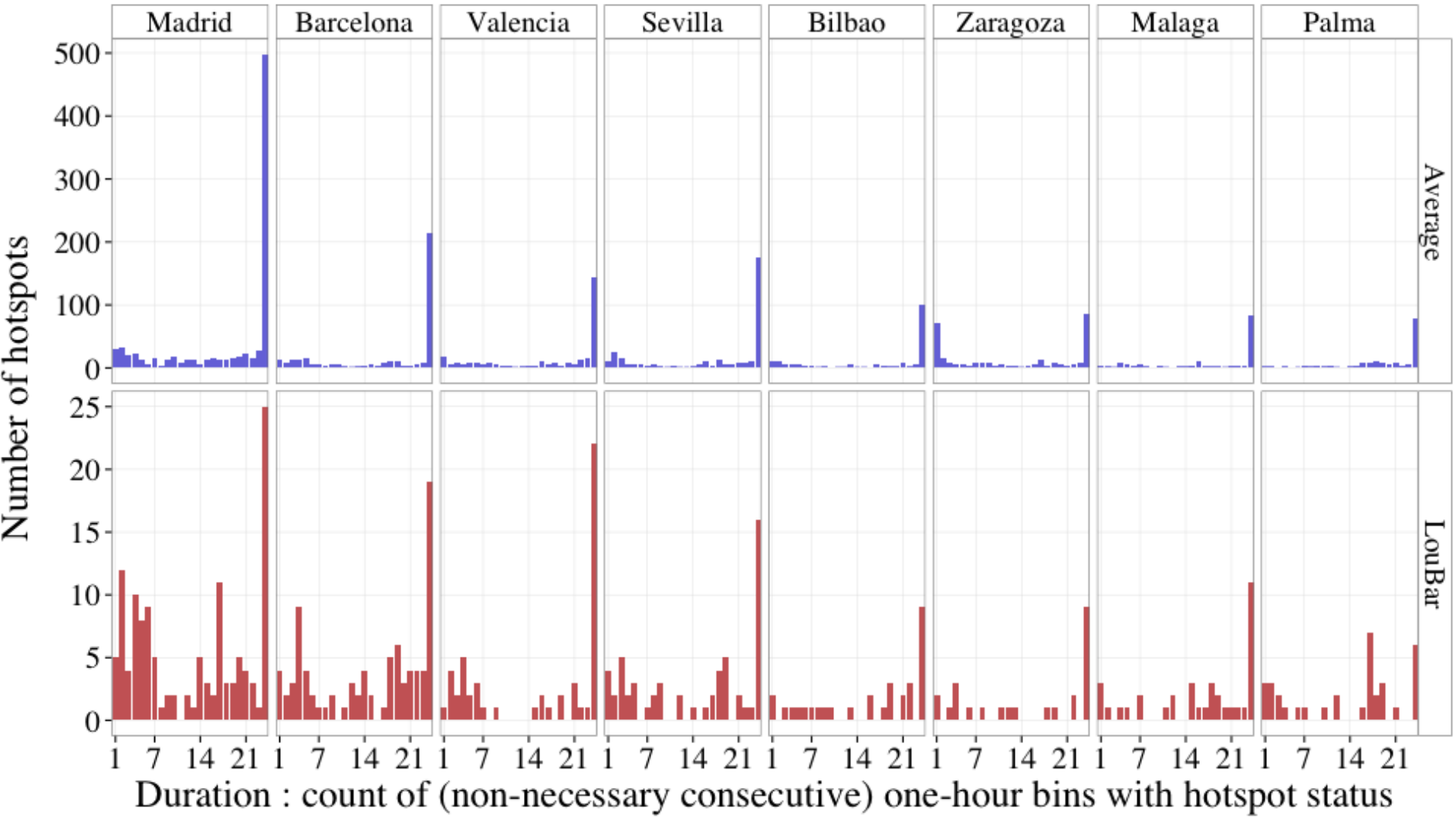
Hotspots


500
100
10
Number of hotspots
H ~ P^0.62
r^2 = 0.68
H ~ P^0.54
r^2 = 0.81
Average
LouBar
200,000
500,000
1,000,000
5,000,000
Population size

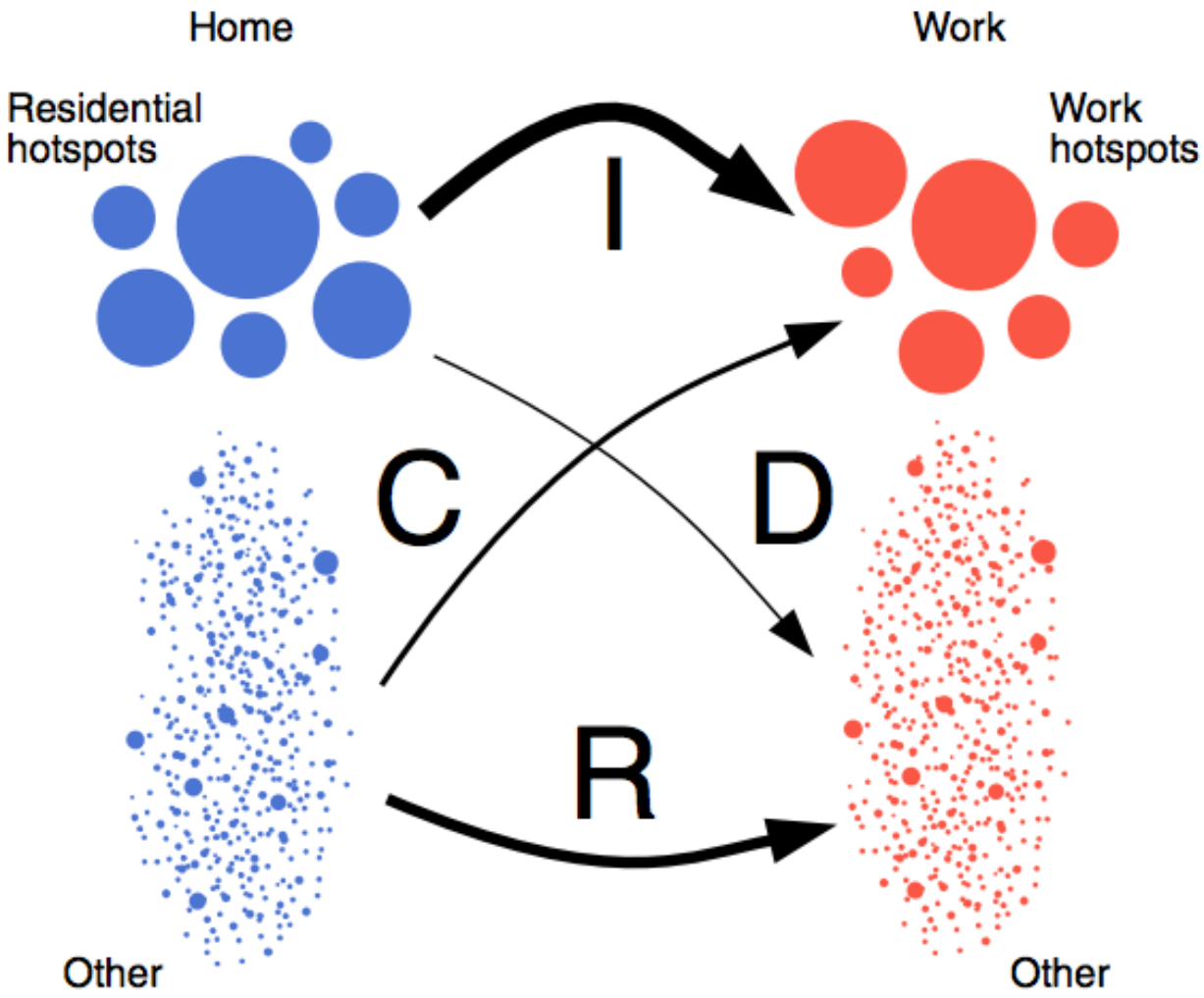
Hotspots


a=500m
a=1km
a=2km
Average
LouBar
Number of hotspots
1000
100
10
H ~ P^0.63
r^2 = 0.67
H ~ P^0.64
r^2 = 0.85
H ~ P^0.62
r^2 = 0.68
H ~ P^0.54
r^2 = 0.81
H ~ P^0.61
r^2 = 0.66
H ~ P^0.4
r^2 = 0.67
500,000
5,000,000
Population size

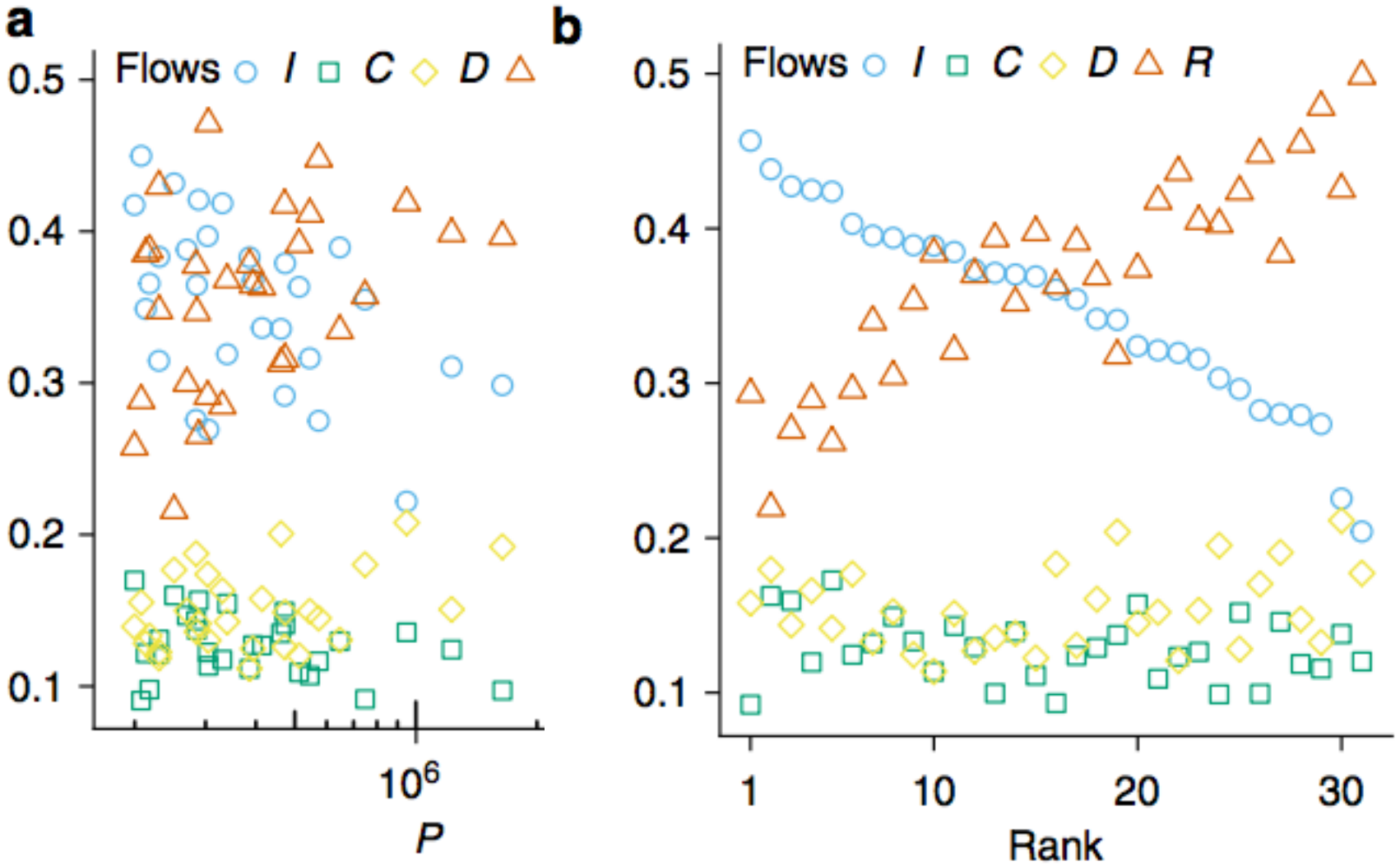
Hotspots


Madrid
Barcelona
Valencia
Sevilla
Bilbao
Zaragoza
Malaga
Palma
Average
LouBar
Number of hotspots
0
100
200
300
400
500
0
5
10
15
20
25
1 7 14 21
Duration : count of (non-necessary consecutive) one-hour bins with hotspot status

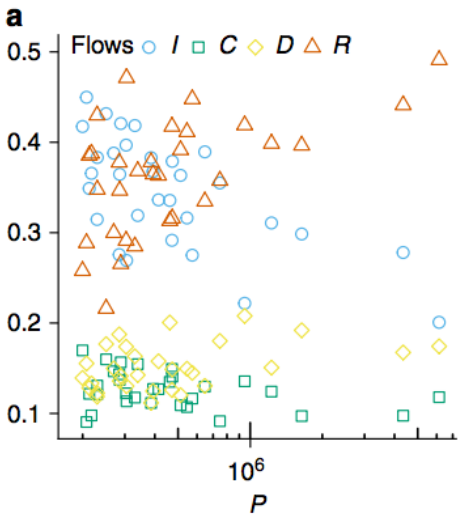
Mobility & Hotspots

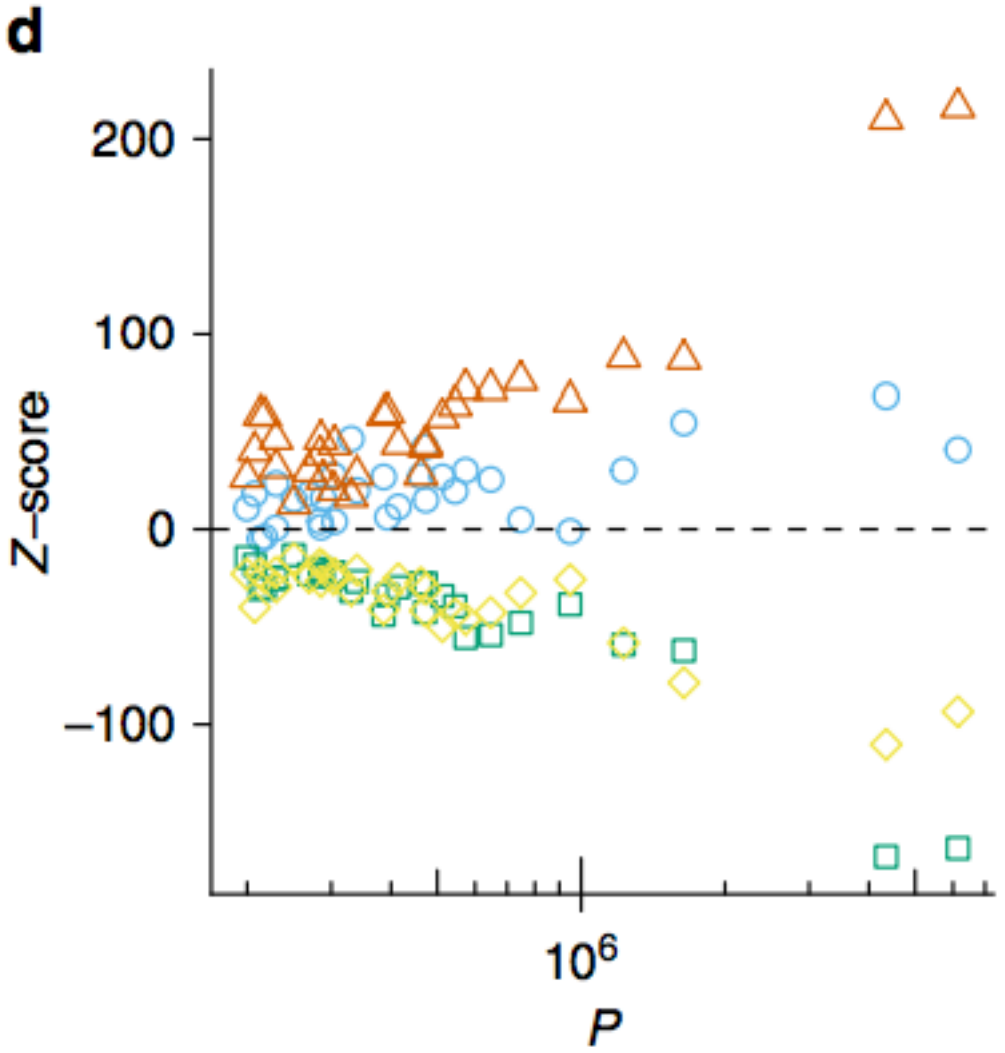


Mobility & Hotspots

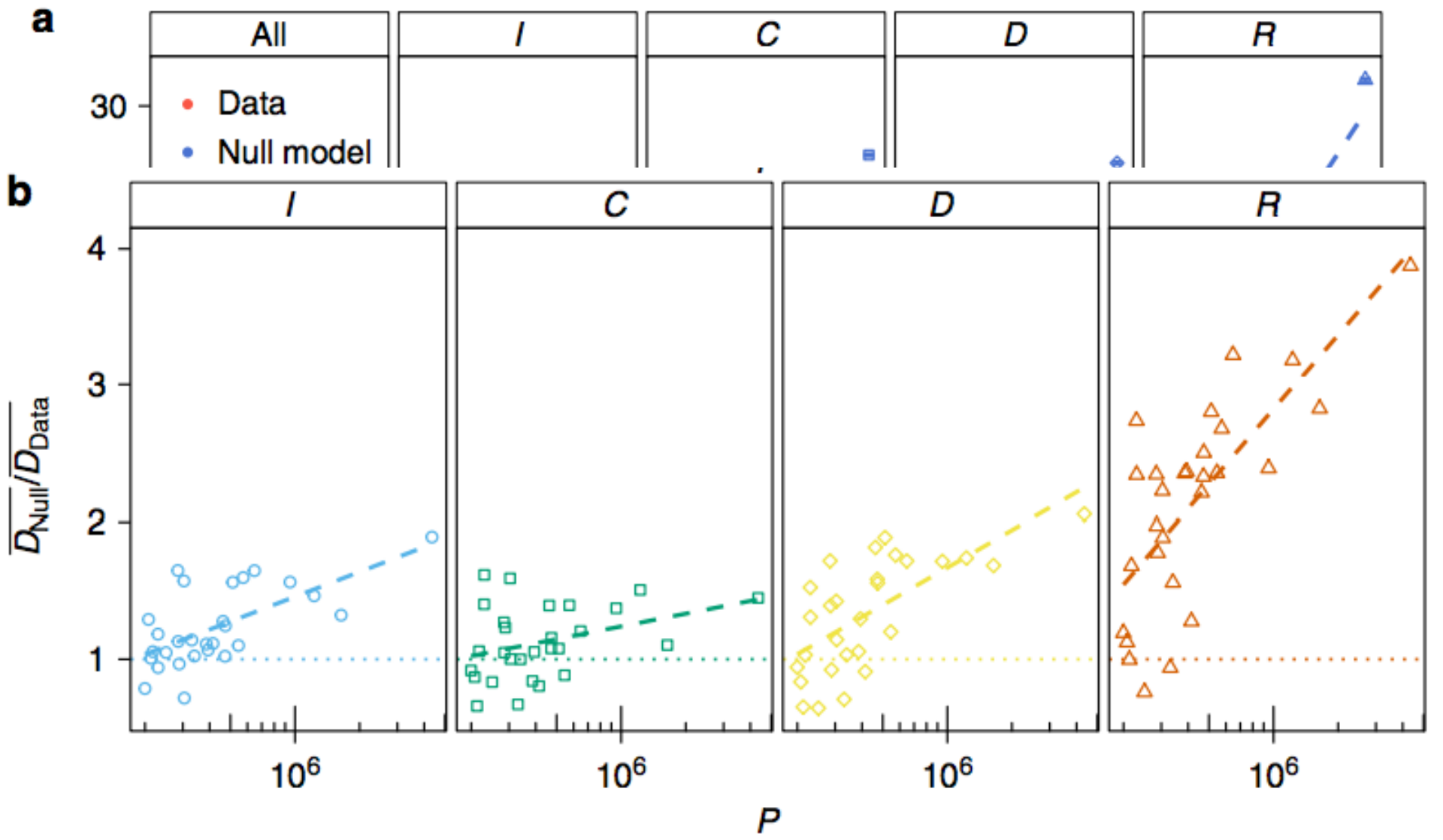


Mobility & Hotspots

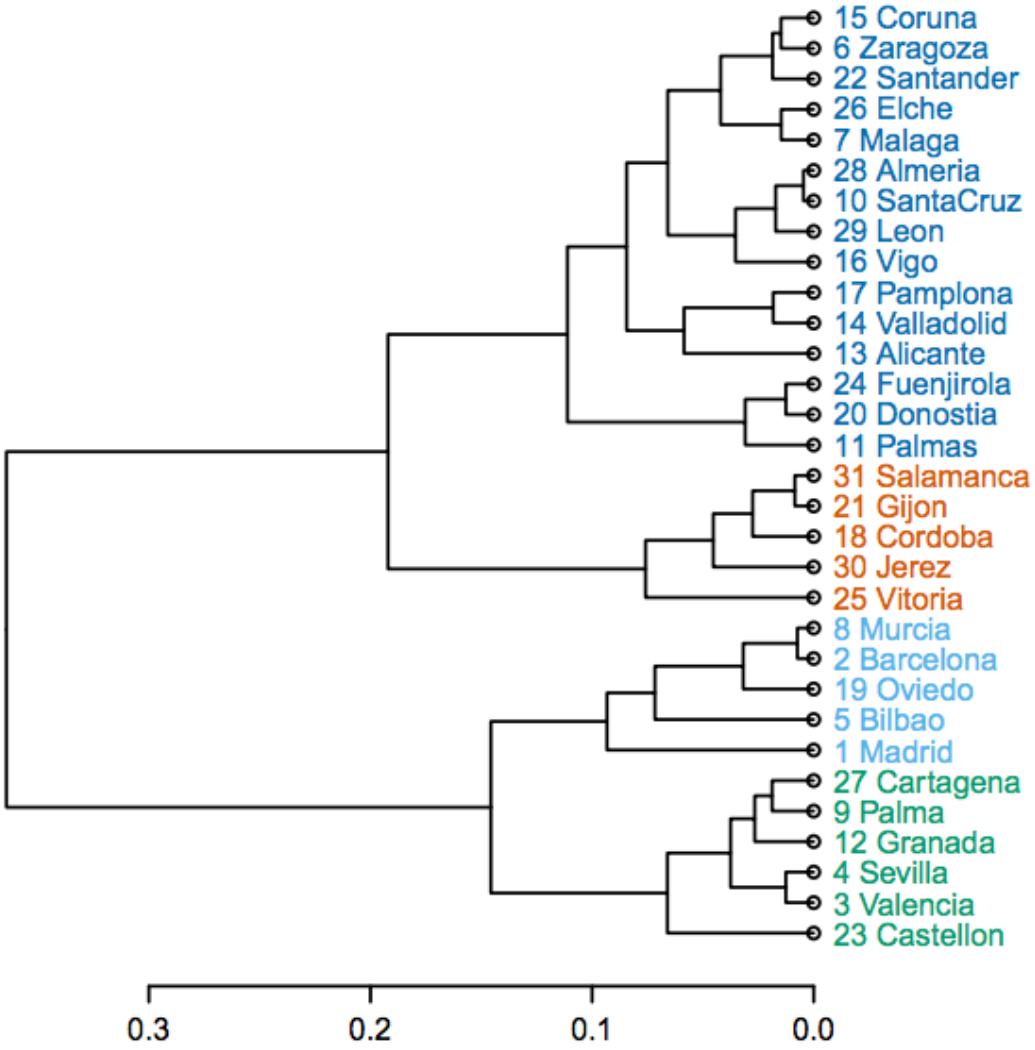




Mobility & Hotspots



Mobility & Hotspots



Conclusions

- We have explored the organization of city hotspots with cell phone data.
- We have quantitatively described how cities "breath" and classify them accordingly.
- A scaling law has been found for the number of hotspots with the city size.
- The hotspots define a classification of flows and cities. R fluxes dominate in large cities.

T. Louail et al, Sci Reports **4**, 5276 (2014).
M. Lenormand et al. PLoS ONE **9**, e105184 (2014).
T. Louail et al., Nature Comm. **6**, 6007 (2015).