Modeling cities and urbanization: cities in the context of development

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Outline

A brief history of cities

What is a city?

The climate and the city

Benchmarks for the modeling of cities

Gravitational city model

A brief history of cities

A brief history of cities

Major historical landmarks:

Neolithic Revolution
10 000 BCE
hunter-gatherer to agricultural practices
permament buildings next to working sites
settlements, villages, small cities
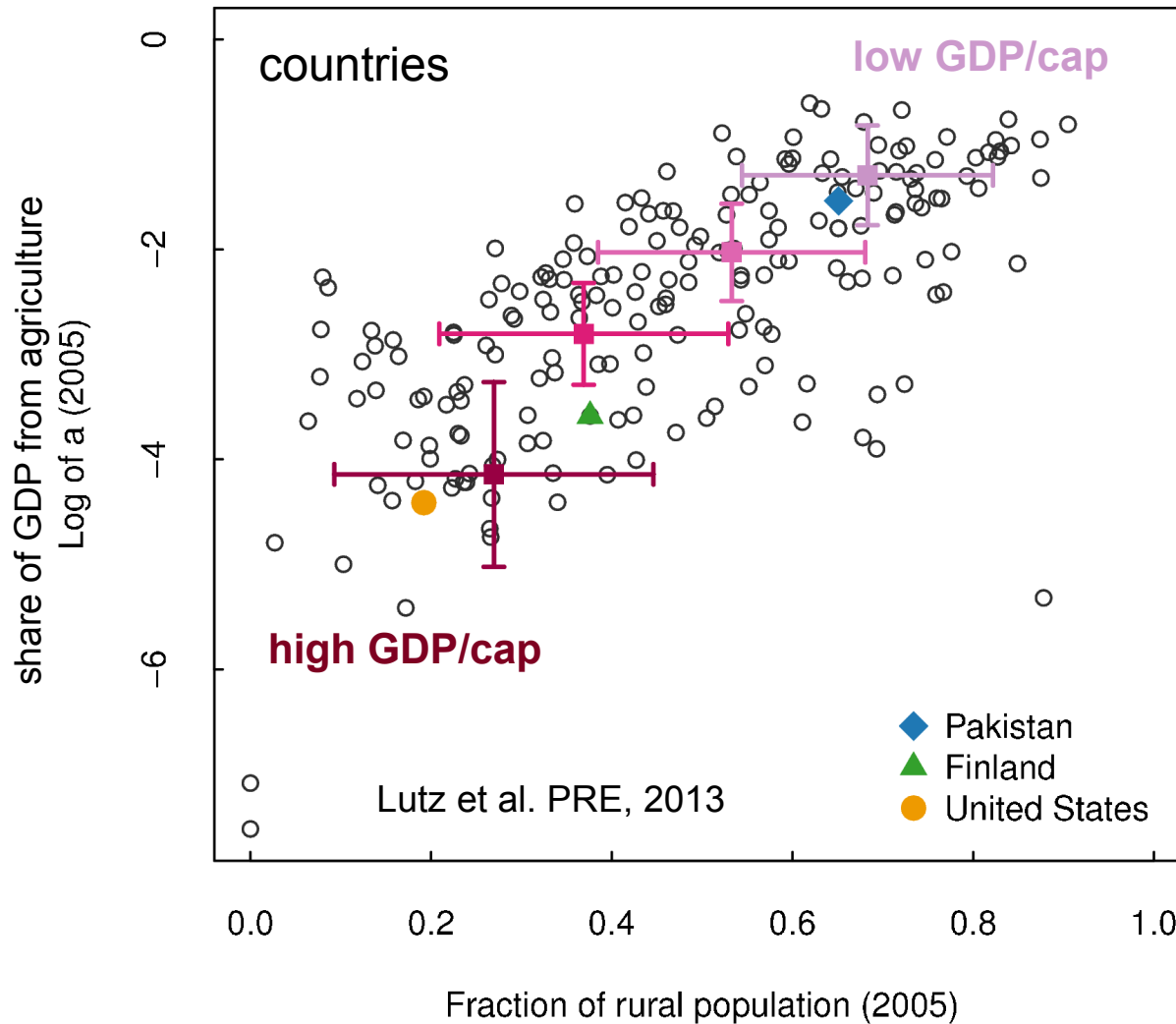
Industrial Revolution
18th..19th century
industrial sector, factories
employment in cities, migration, pop. growth
tall buildings (steel frame, elevators)
modern cities

Globalization
complex and controversial
relocation of production processes
    to less developed countries
corresponding cities
migration
mega-cities

A brief history of cities

What is a city?

What is a city?

"constructional design of the environment" (Benevolo 2007)

"city as physical feature, as artificially modeled artifact, as peace of designed environment" (Lampugnani 2011)

What is a city?

"constructional design of the environment" (Benevolo 2007)

"city as physical feature, as artificially modeled artifact, as peace of designed environment" (Lampugnani 2011)

"cities are dense agglomerations where, historically, people have come together to trade and engage in diverse social relationships" (Batty 2011)

"they are considered points in space where the friction of distance that restricts our ability to relate to one another is minimized" (Batty 2011)

What is a city?

Figure I.1. Urban and rural populations of the world: 1950-2030

World Urbanization Prospects:
The 2003 Revision (UN, 2004)
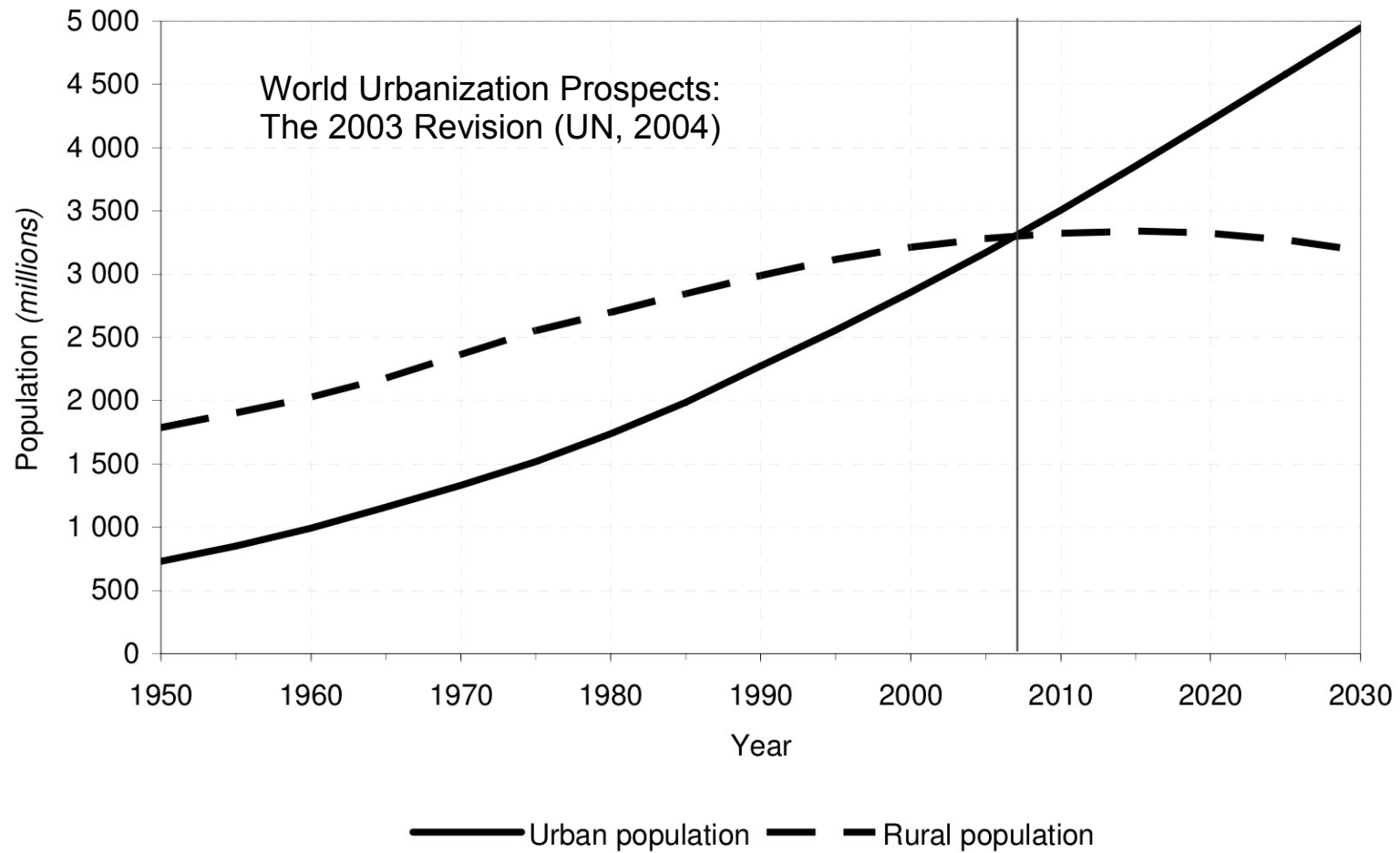
What is a city?

Problem:

no strict definition for a city!
Certain classifications, e.g. town, city, municipality, urban area, etc.

Examples for city definities:
Brazil: urban seat of a municipality
China: > 100,000 of non-agricultural population in an urbanized area
Chile: urban entity with more than 5,000 inhabitants
India: urban area: municipality, corporation board & place satisfying the following 3 criteria simultaneously: > 5,000 residents; > 75% of male working people in non-agricultural pursuits; a density of population of at least 400 per km^2
Japan: Population > 50,000, 60% or more of buildings are in the city centre, 60% of residents working for non-primary sectors of the economy, has a system to function as a city.
Russia: > 12.000 people and number of employees in agriculture < 15%
USA: matter of state law, Illinois > 2,500, Nebraska > 800, form of government
UK: by letters patent, England and Wales, prior to 1907: criterion was the establishment of an Anglican Cathedral

What is a city?

Descriptive views on cities could be categorized into:

(i)   people
(ii) usage
(iii) physical features

which are related/correlated, e.g.
  employees work in offices in tall buildings

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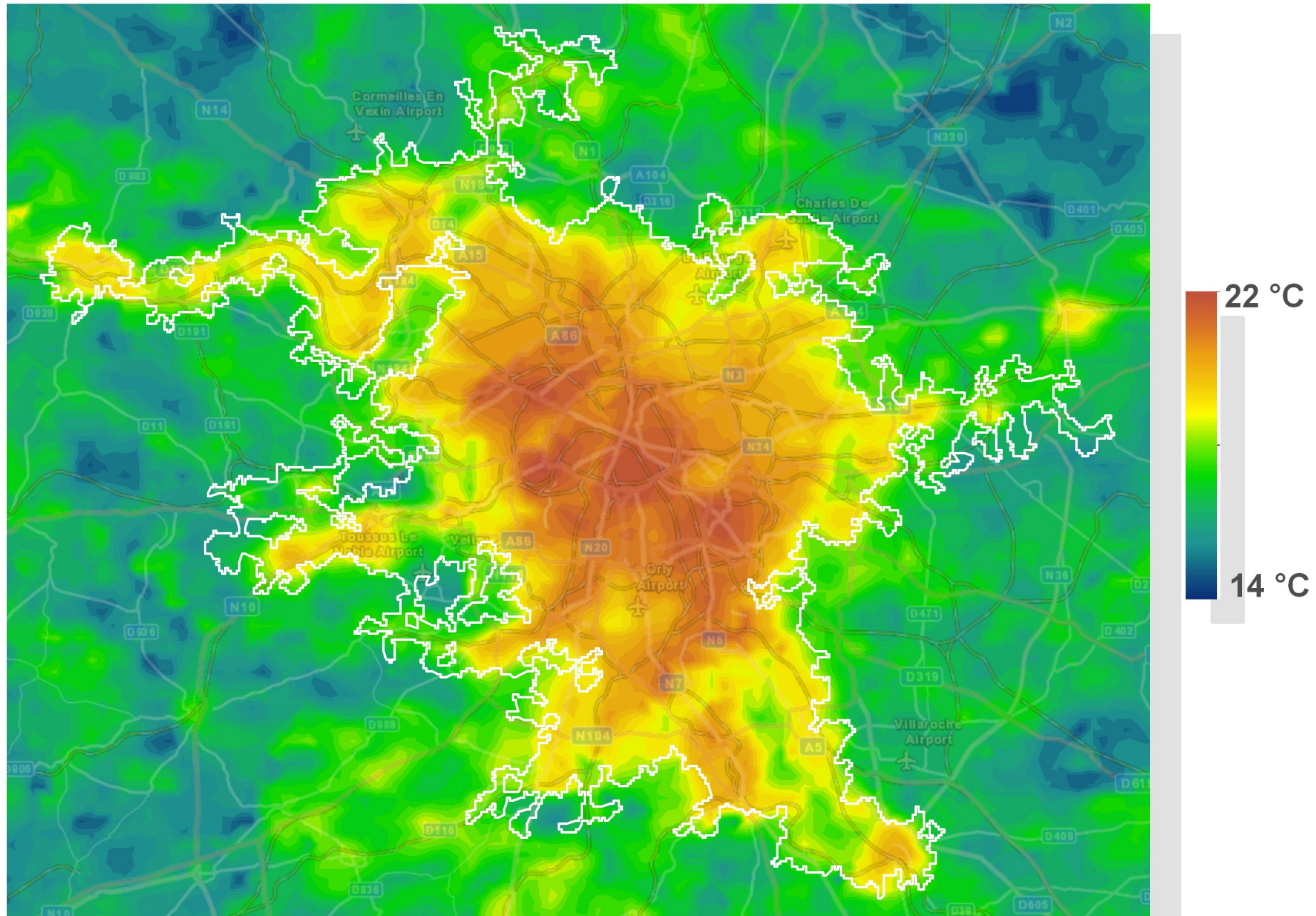
We (mostly) employ physical definition:
Cities as maximally connected urban clusters
    City Clustering Algorithm (CCA)
    physical phenomena
    data availability

The climate and the city

The climate and the city: Paris

The climate and the city: Zhou, GRL, 2013

London
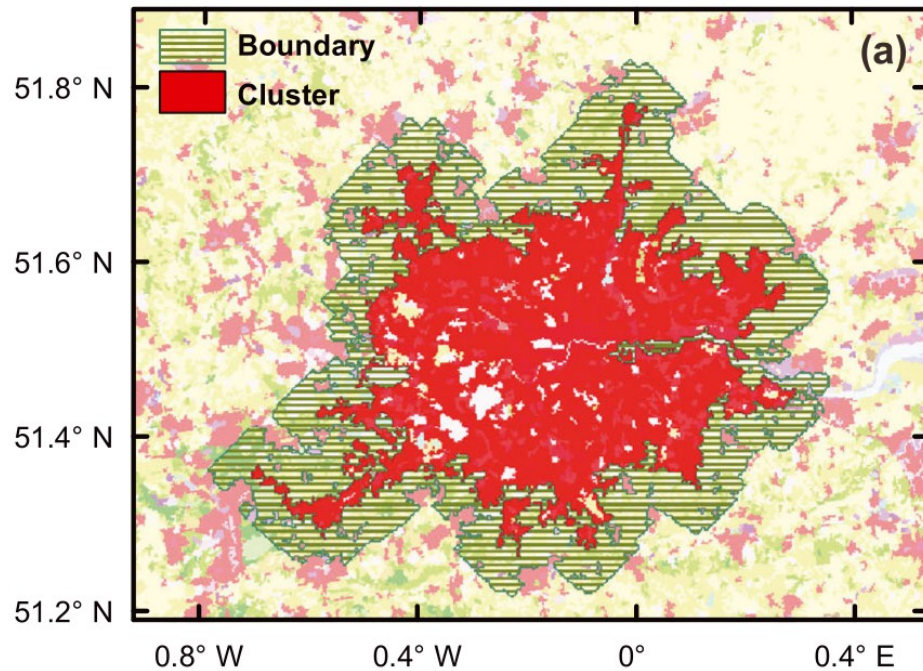
Land cover
Corine
250m
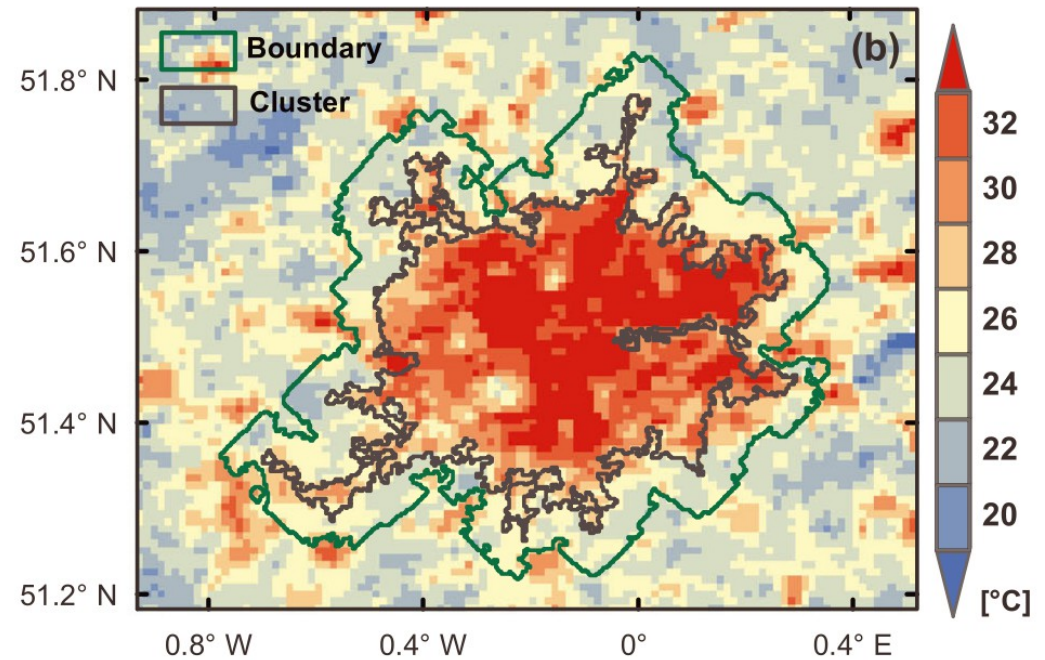
Surface temperature
Modis
1000m

The climate and the city: Zhou, GRL, 2013

Size dependence (Europe, 130000 city clusters)
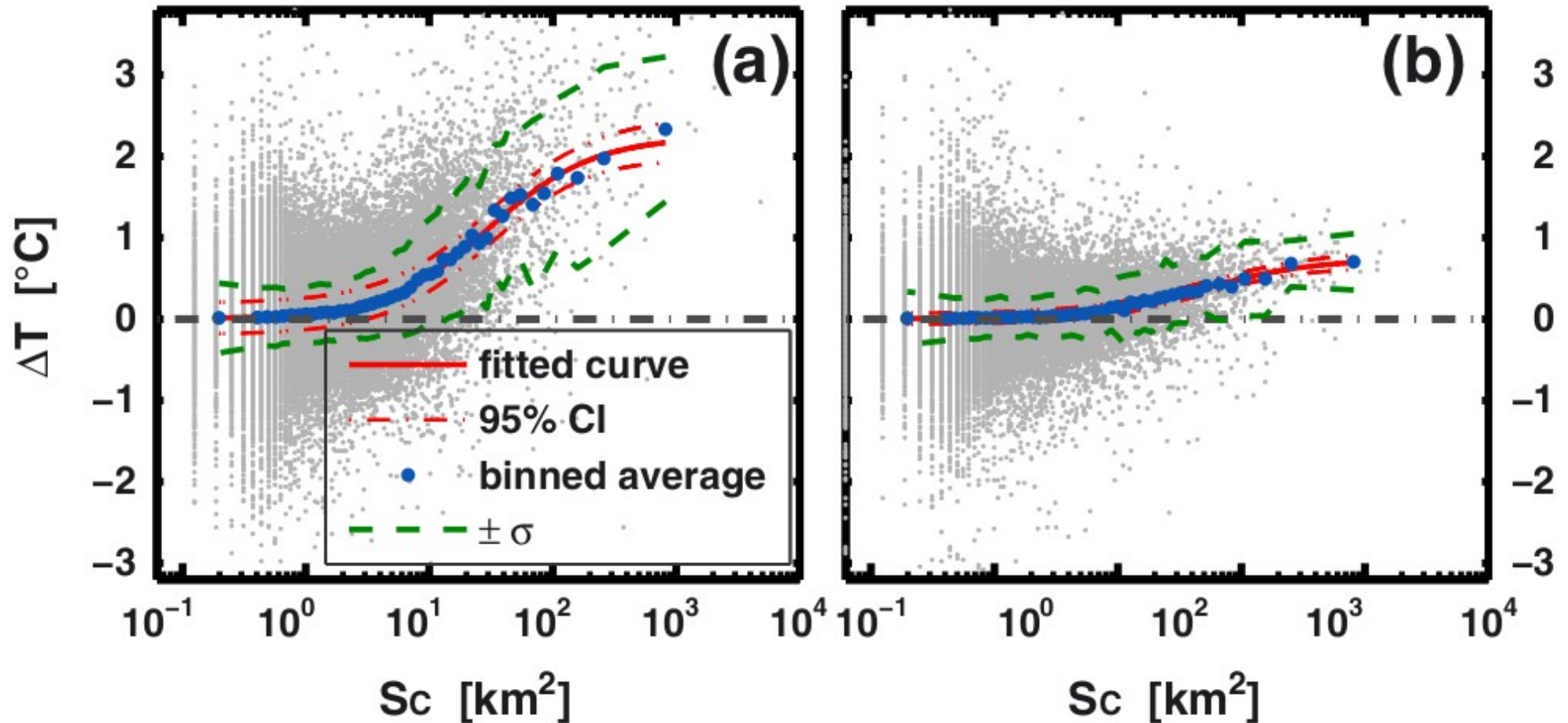
The climate and the city: Zhou, GRL, 2013

Dependence on background temperature (new seasonality)

Paris
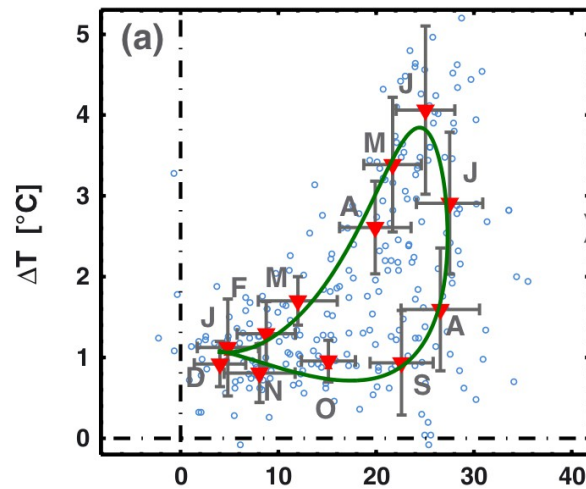
Milan
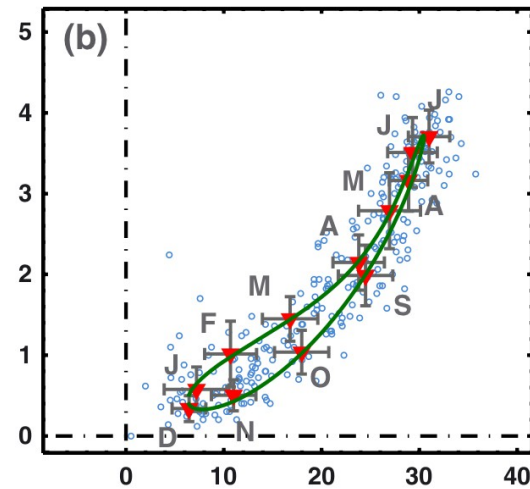
Madrid
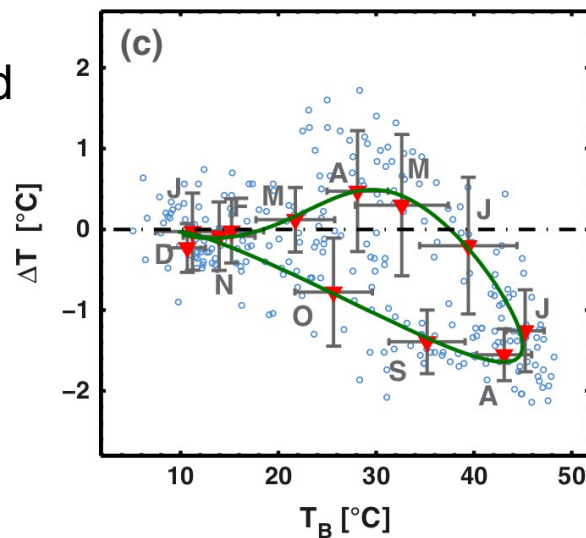
Nikosia
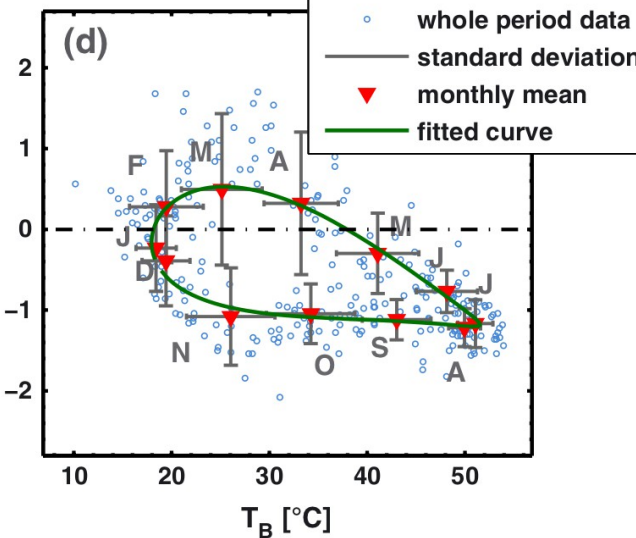
Benchmarks for the modeling of cities

Benchmarks for the modeling of cities

A reductionist point of view …

(i)   City **size** distribution
      power-law probability density, exponent ≈2
      (Zipf-Auerbach law)

Abb. 10 EDVARD MUNCH, **Felix Auerbach**, 1906,
Öl auf Leinwand, 83,8 x 76,2 cm, Verbleib
unbekannt

GB

Rozenfeld AER 2011
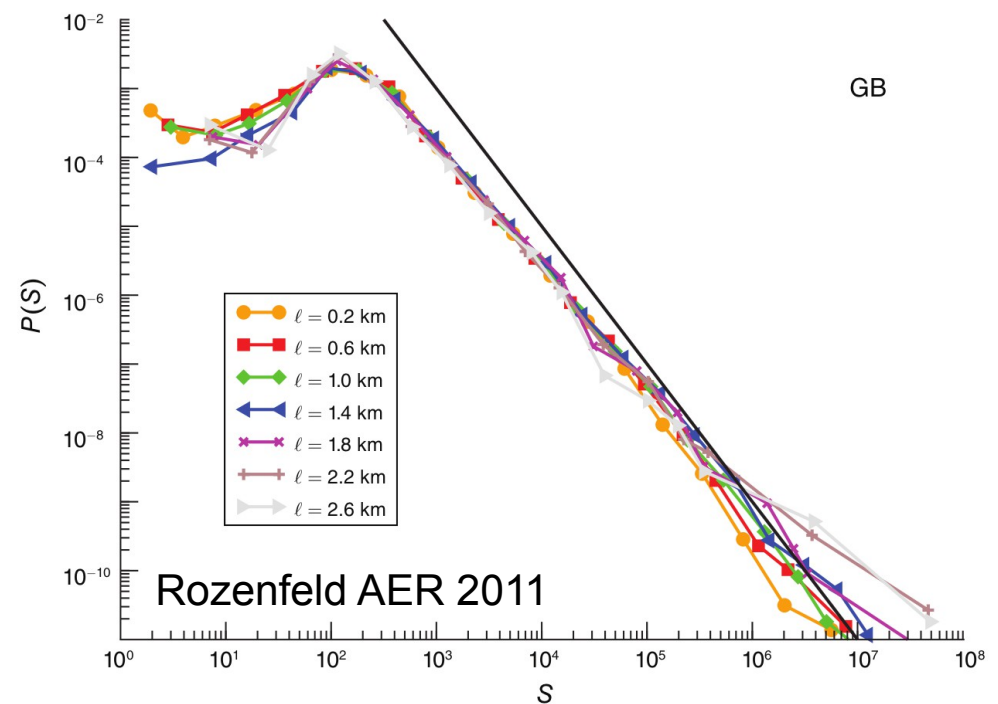
FIGURE 4. PROBABILITY DISTRIBUTION $P(S)$ FOR GB AT DIFFERENT COARSE-GRAINING SCALES ℓ

Note: The black solid line denotes a power law function with density exponent -2, i.e., Zipf's law.

Benchmarks for the modeling of cities

A reductionist point of view …

(ii) City **growth**
 power-law dependence of
 growth-rates on size
 (generalized Gibrat's law)
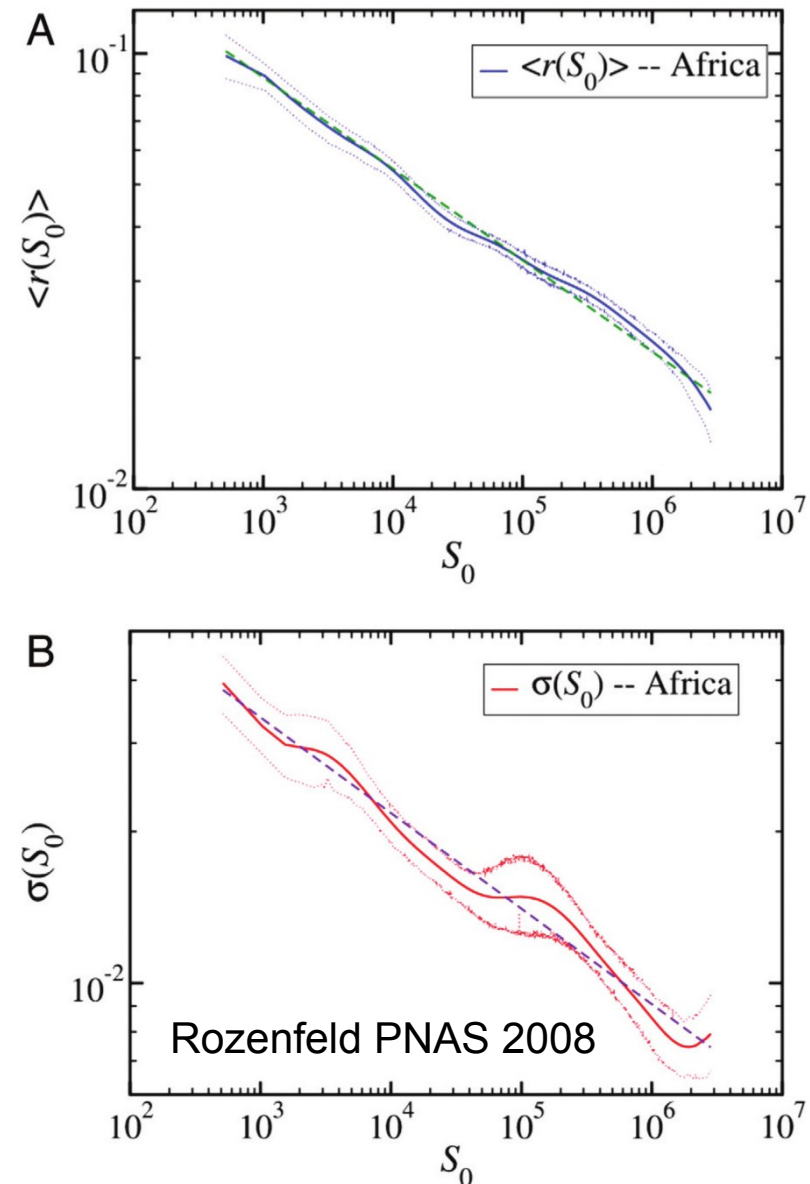
Rozenfeld PNAS 2008

Benchmarks for the modeling of cities

A reductionist point of view …

(i)   City **size** distribution
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(ii) City **growth**
       power-law dependence of growth-rates on size
       (generalized Gibrat's law)

(iii) **Fractality**
       Self-similarity, fractal dimension between 1 and 2
       (e.g. via box-counting)

Gravitational city model

Gravitational city model

*"Everything is related to everything else,
but near things are more related
than distant things."*

(W.R. Tobler, 1970)

Gravitational city model

The cells of a grid with the coordinates i can either be occupied ($w_i = 1$) or empty ($w_i = 0$). Iteratively each site is tested for being populated. Therefore, the probability to become populated is given by

$$p_i = C \frac{\sum_{j \neq i} w_j d_{i,j}^{-\gamma}}{\sum_{j \neq i} d_{i,j}^{-\gamma}} \quad , \tag{1}$$

where $d_{i,j}$ is the distance between the points i and j. The index j runs over all sites with $w_j = 0$, i.e. already populated sites are not further considered. Finally, the probabilities are normalized according to $\max(p_i) = 1$.

Example

630 x 630
$\gamma=2.5$
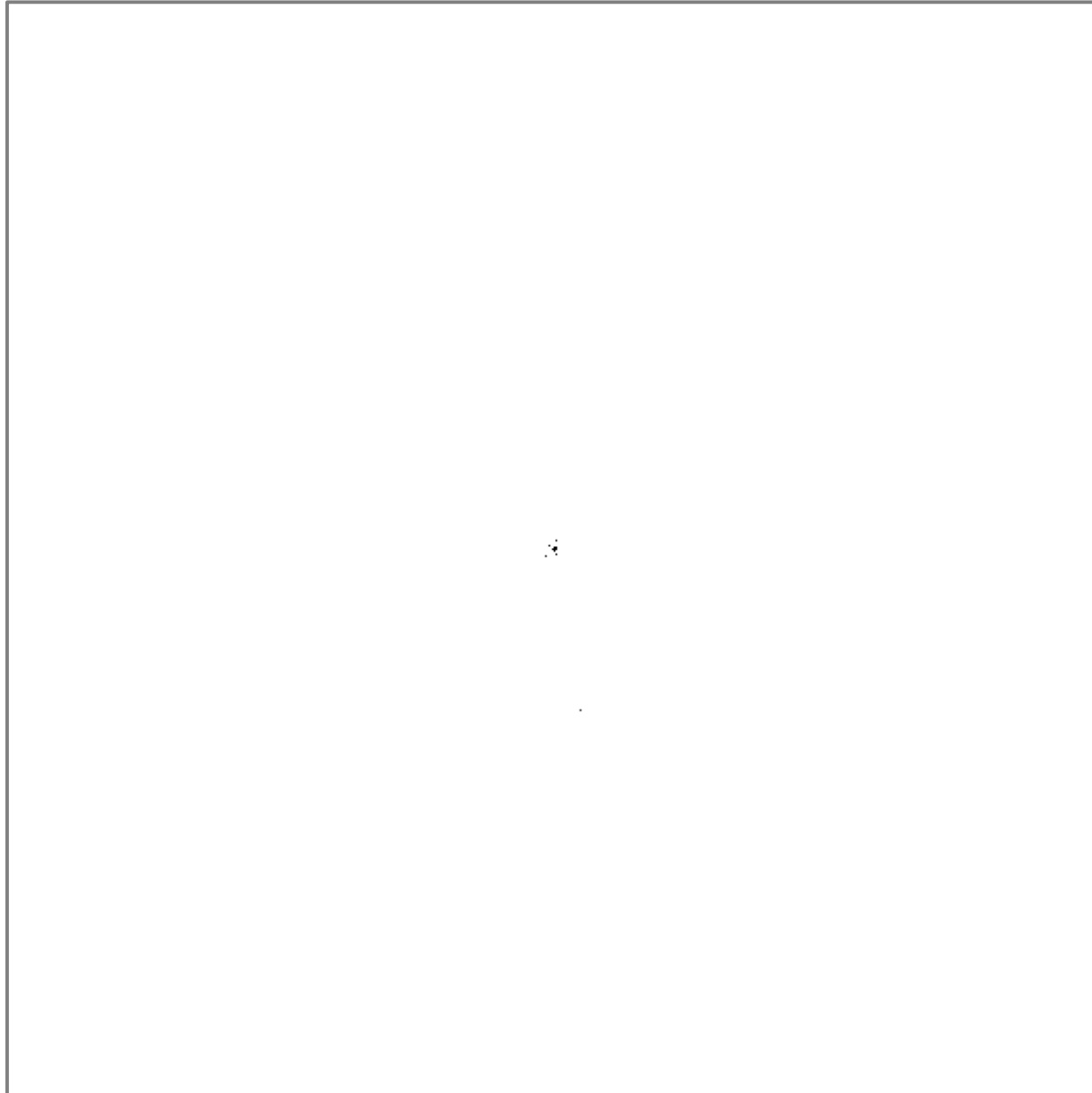
Example
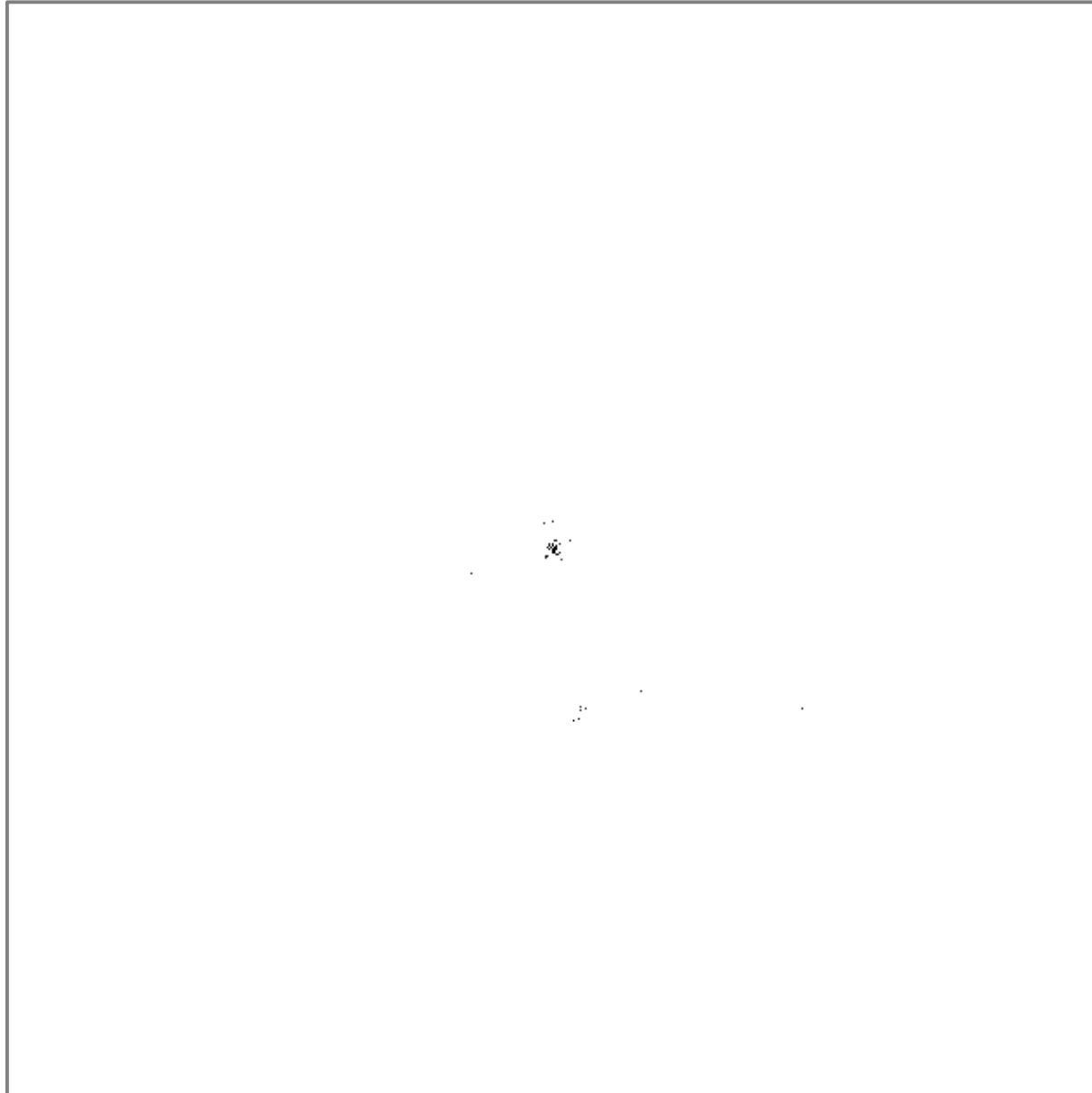
Example
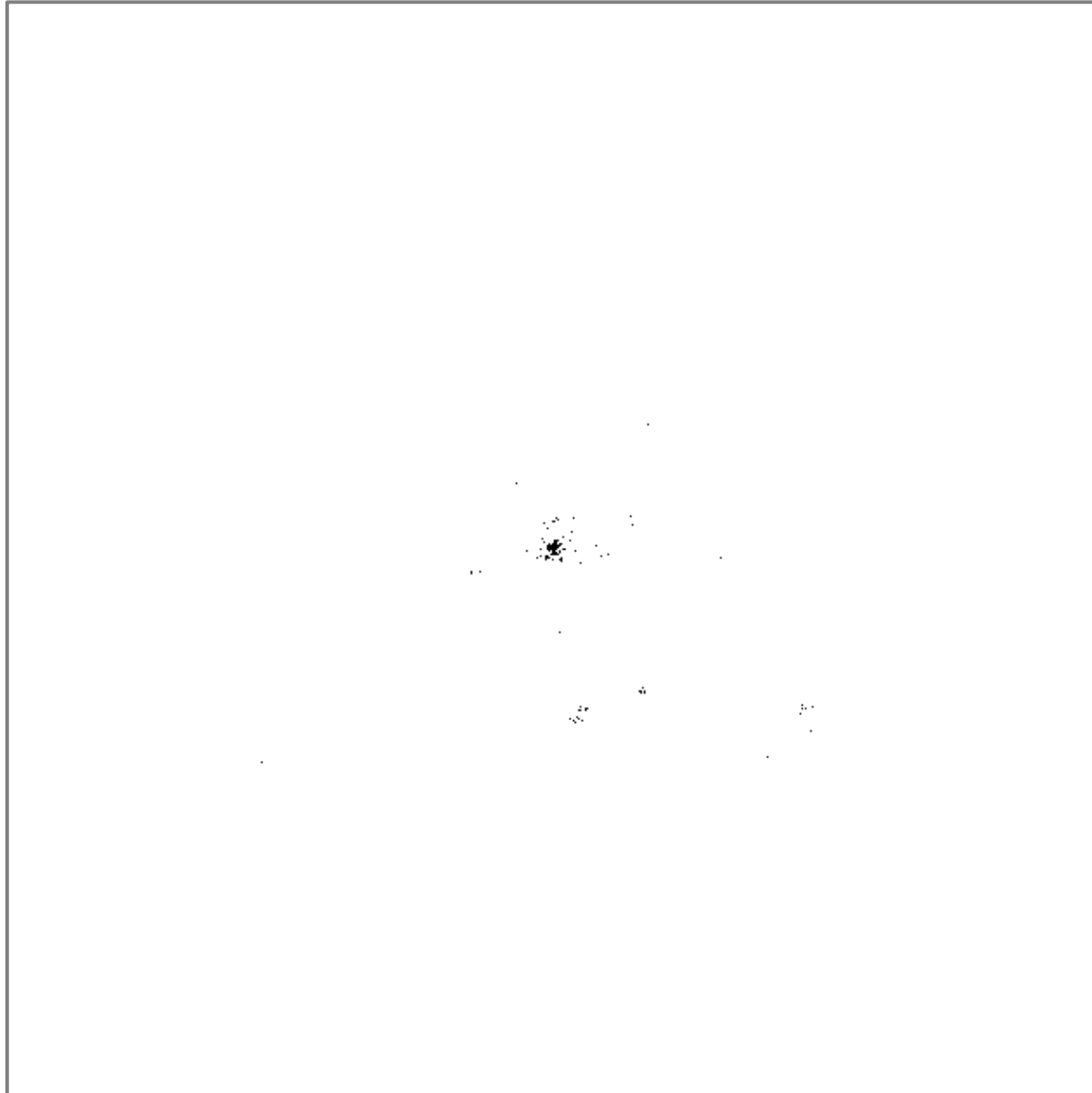
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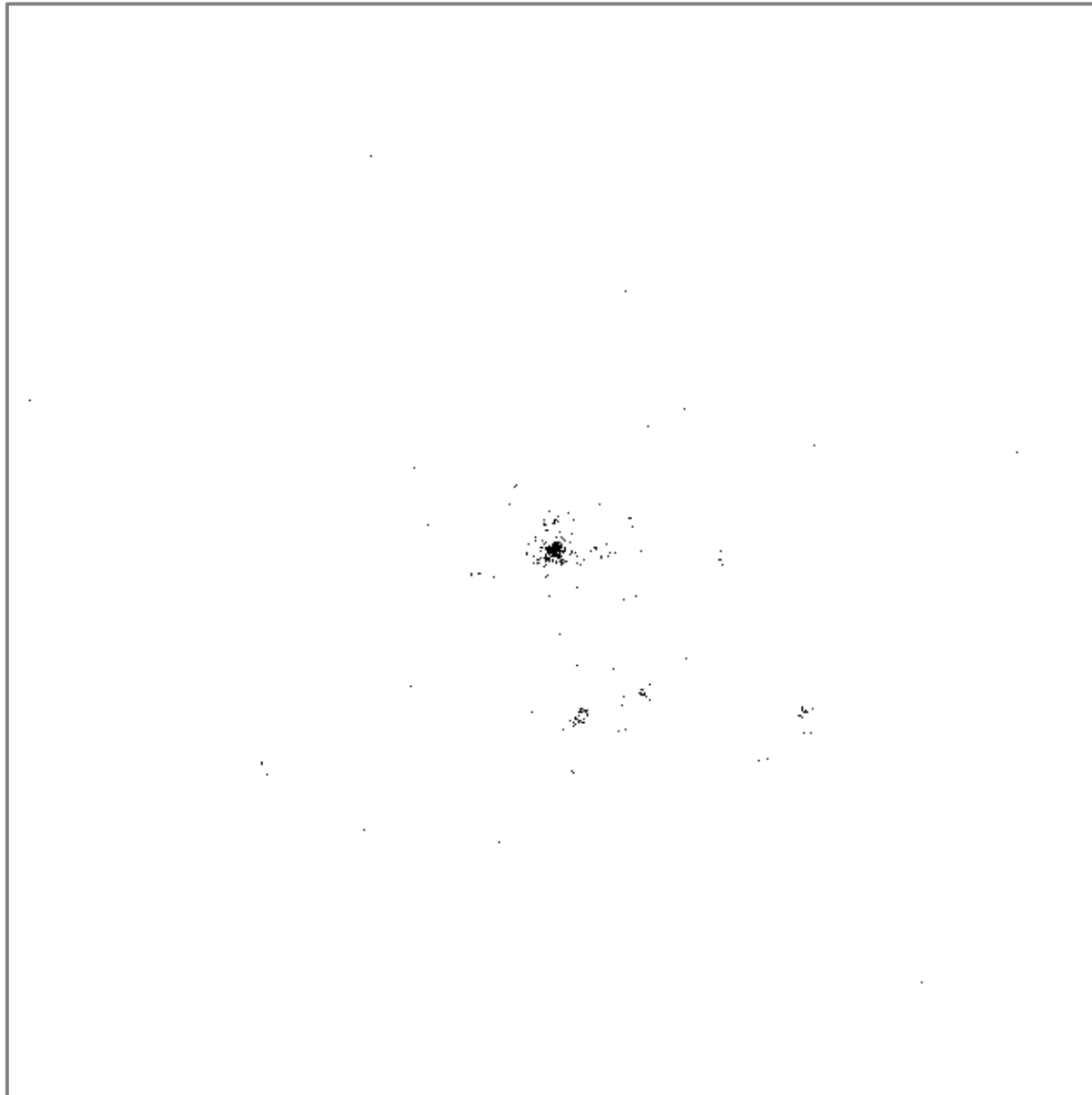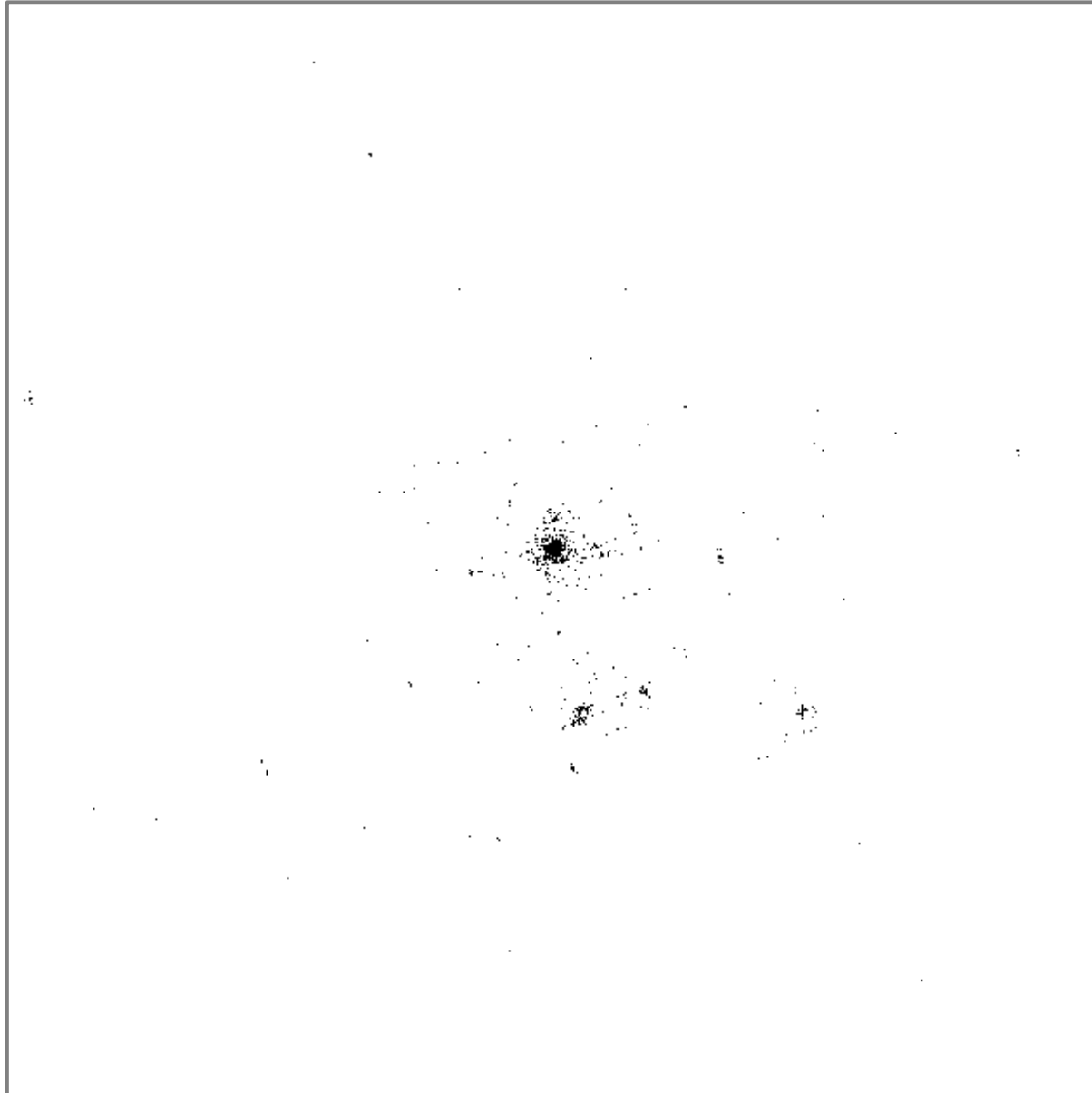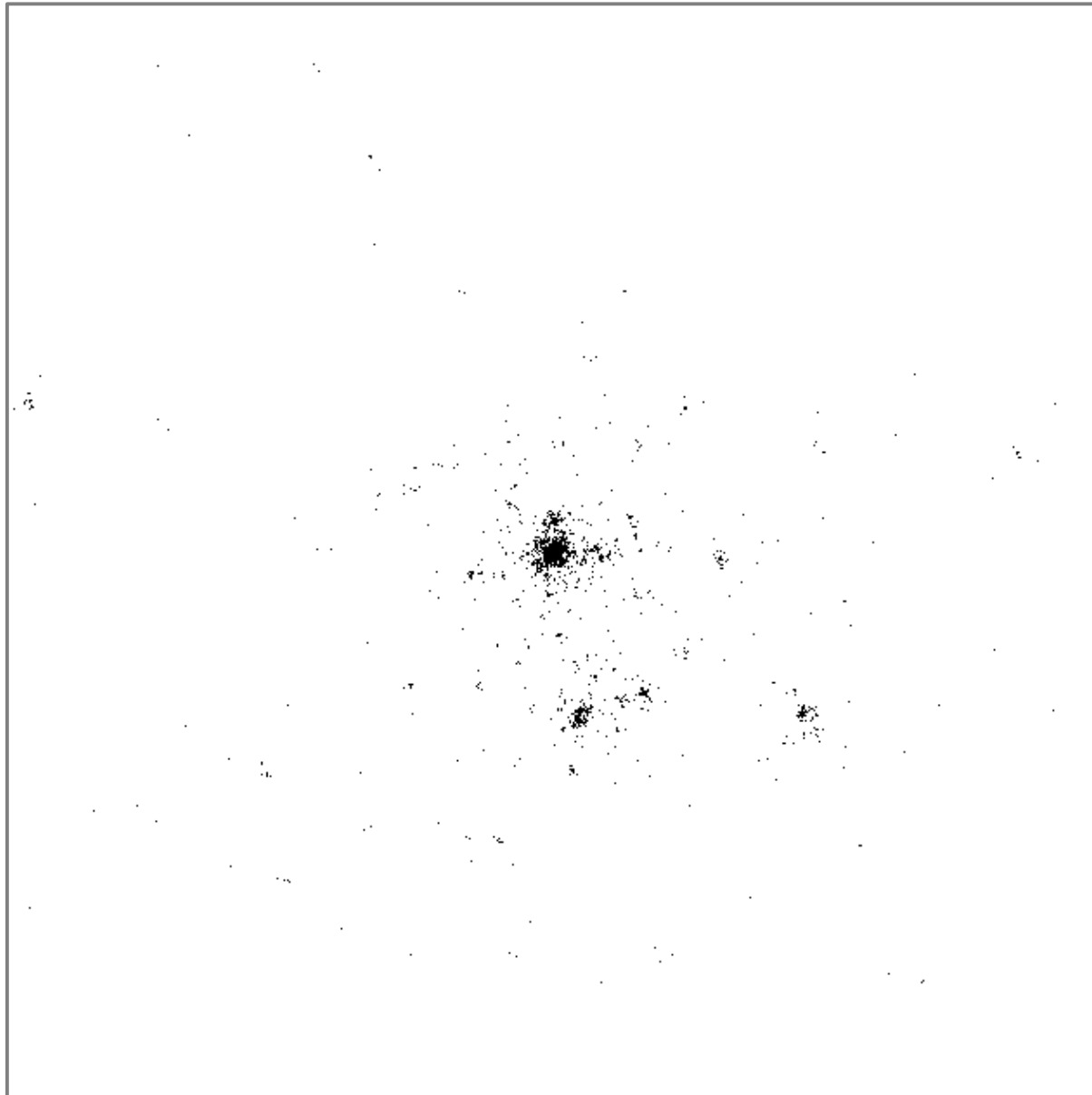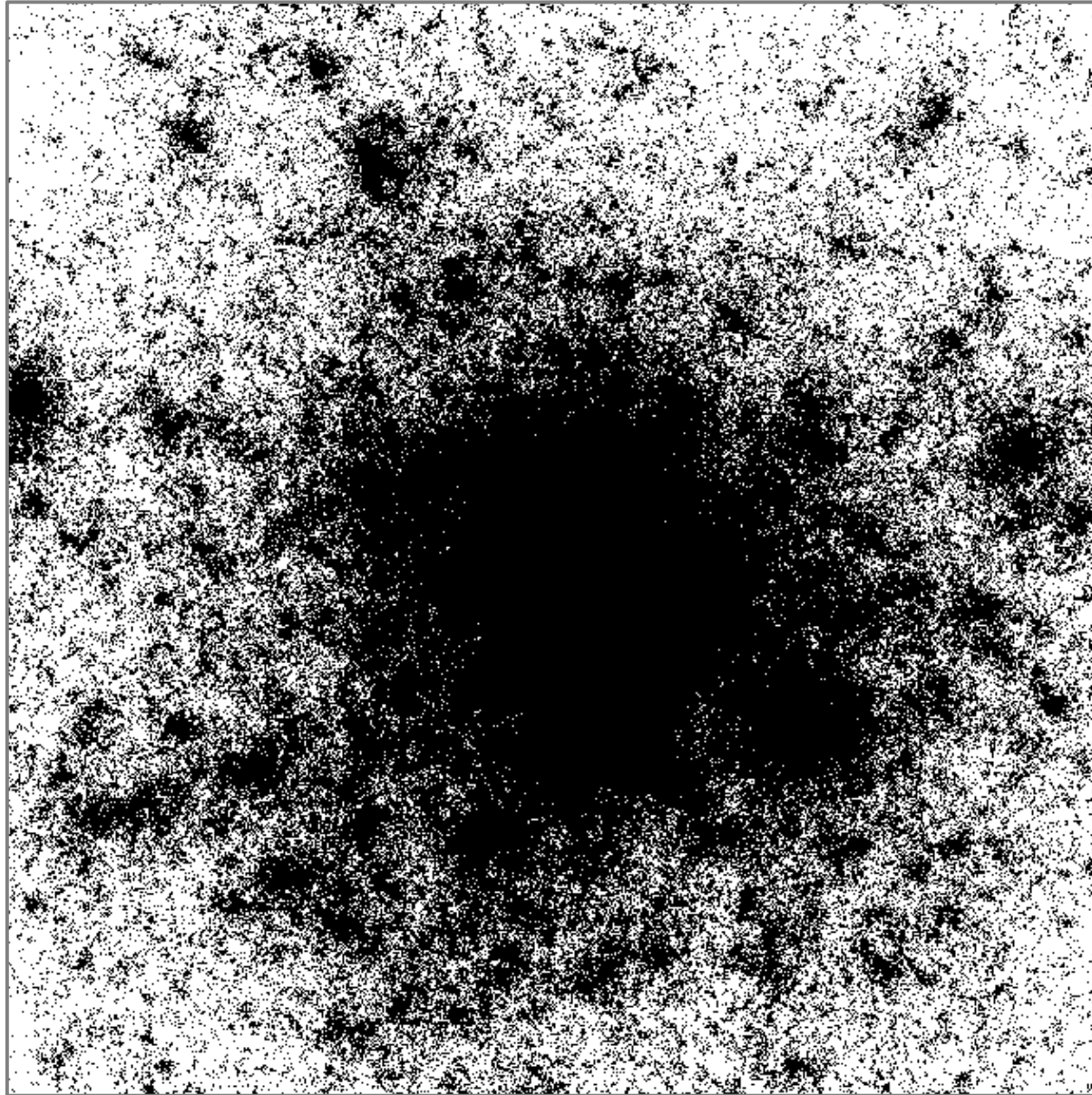
Example
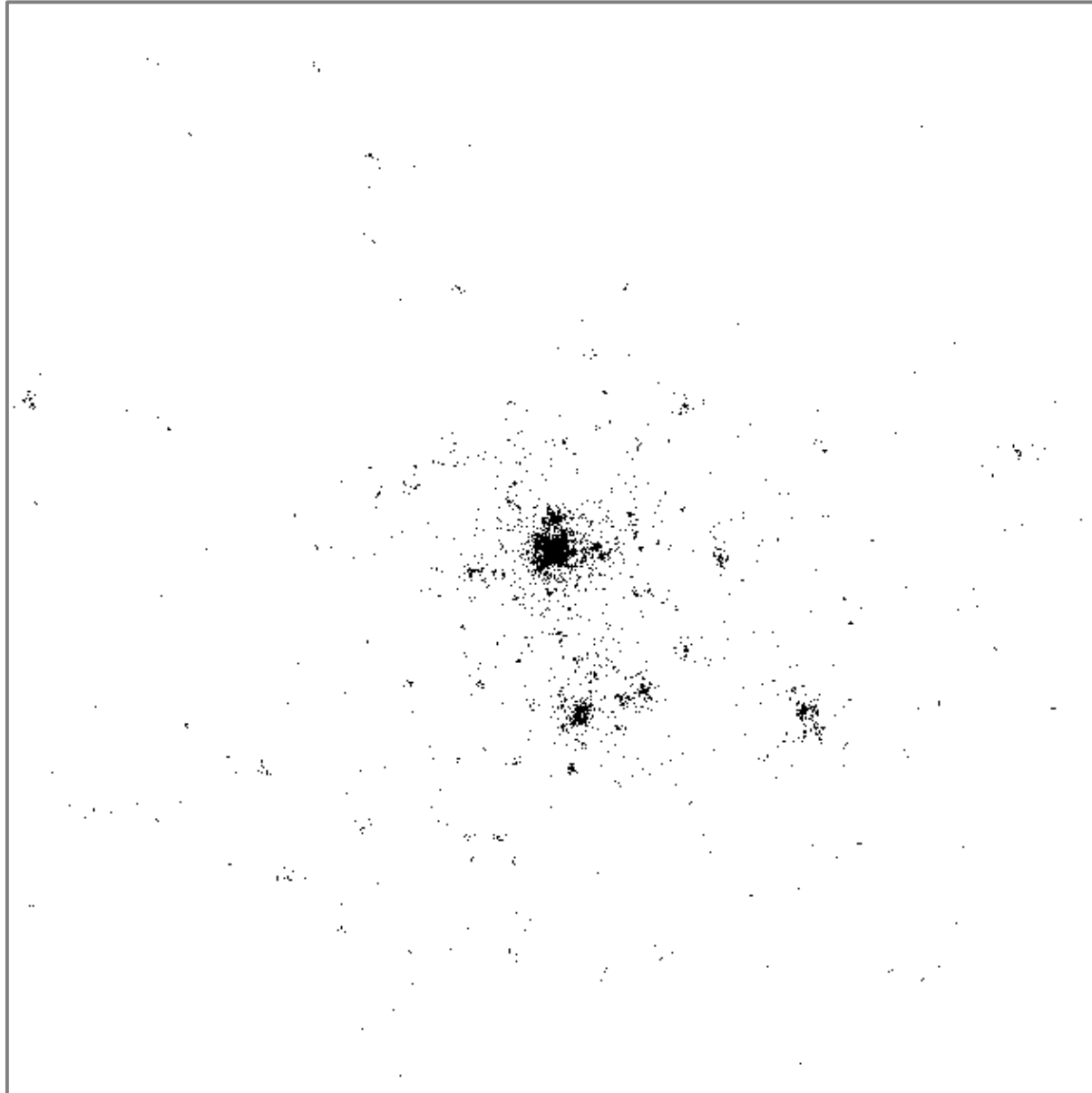
Example
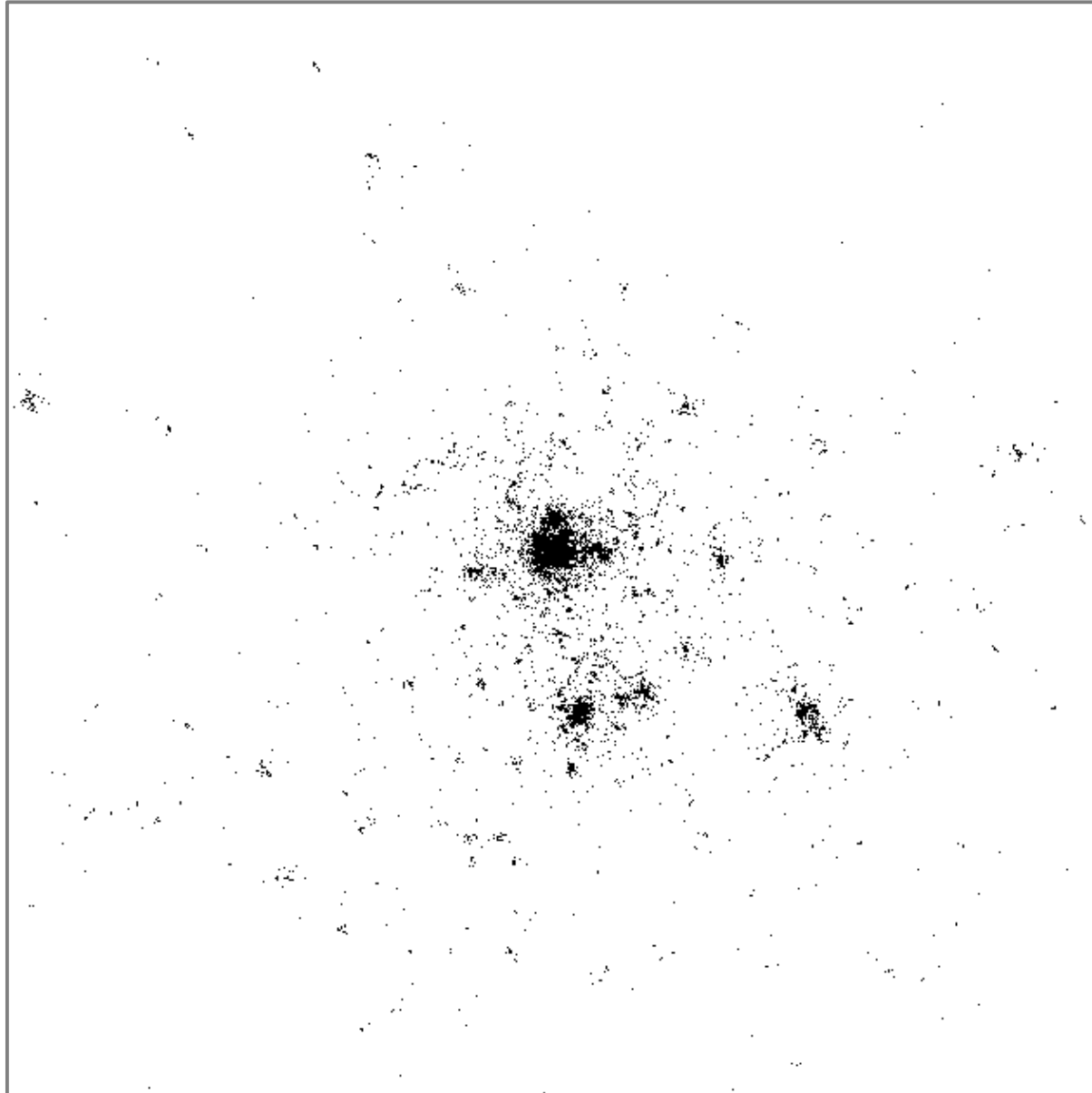
Example
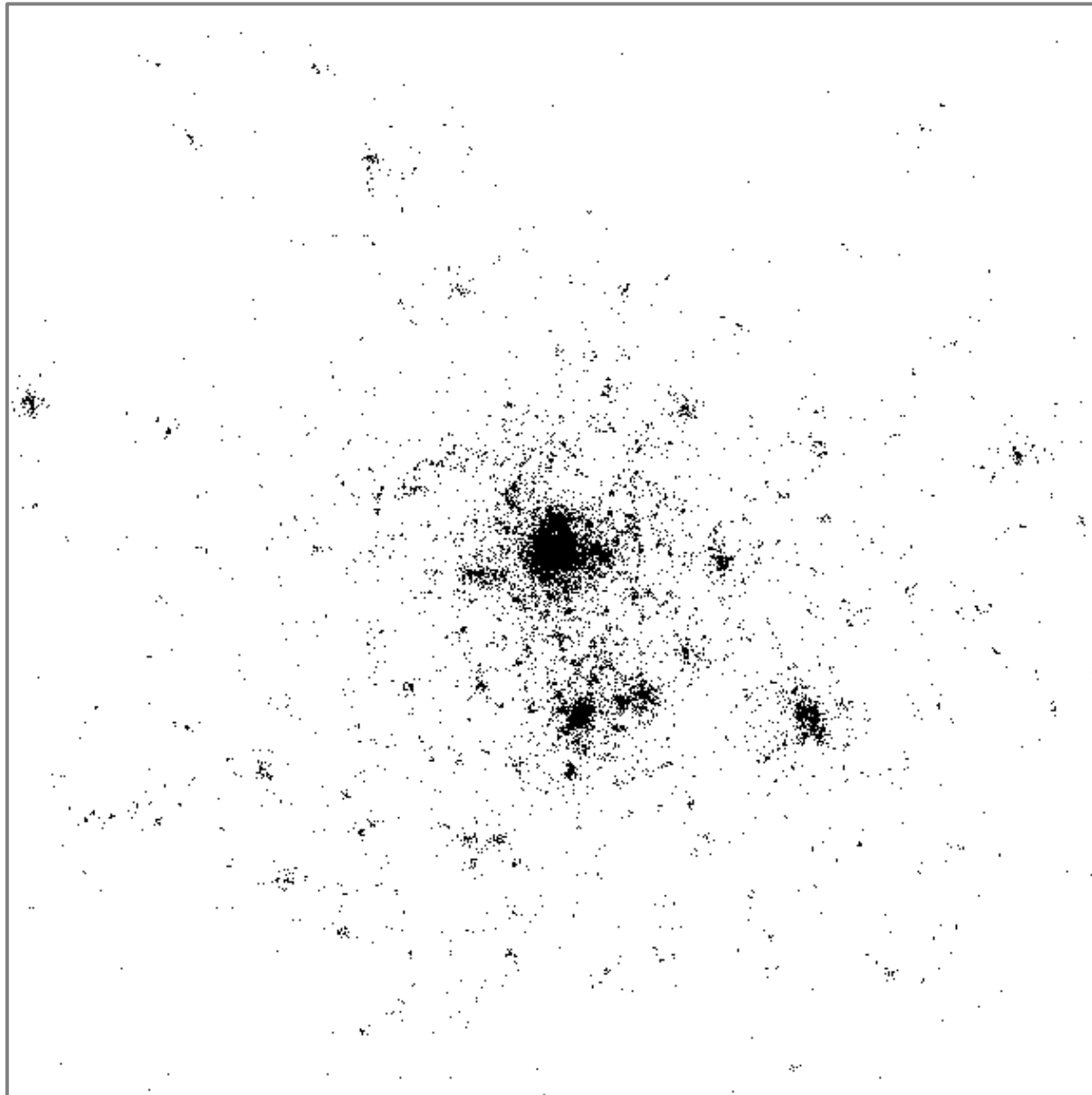
Example
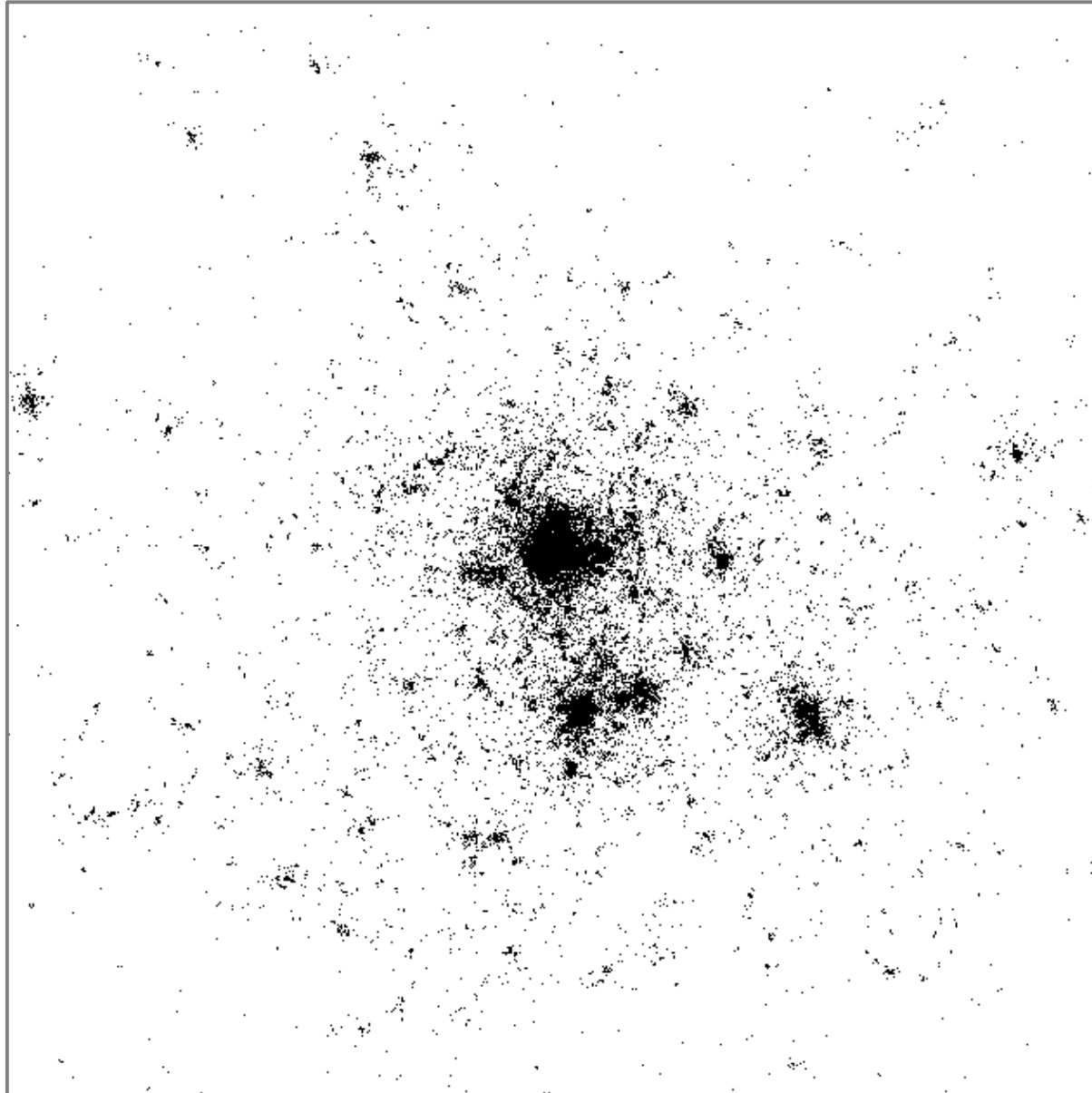
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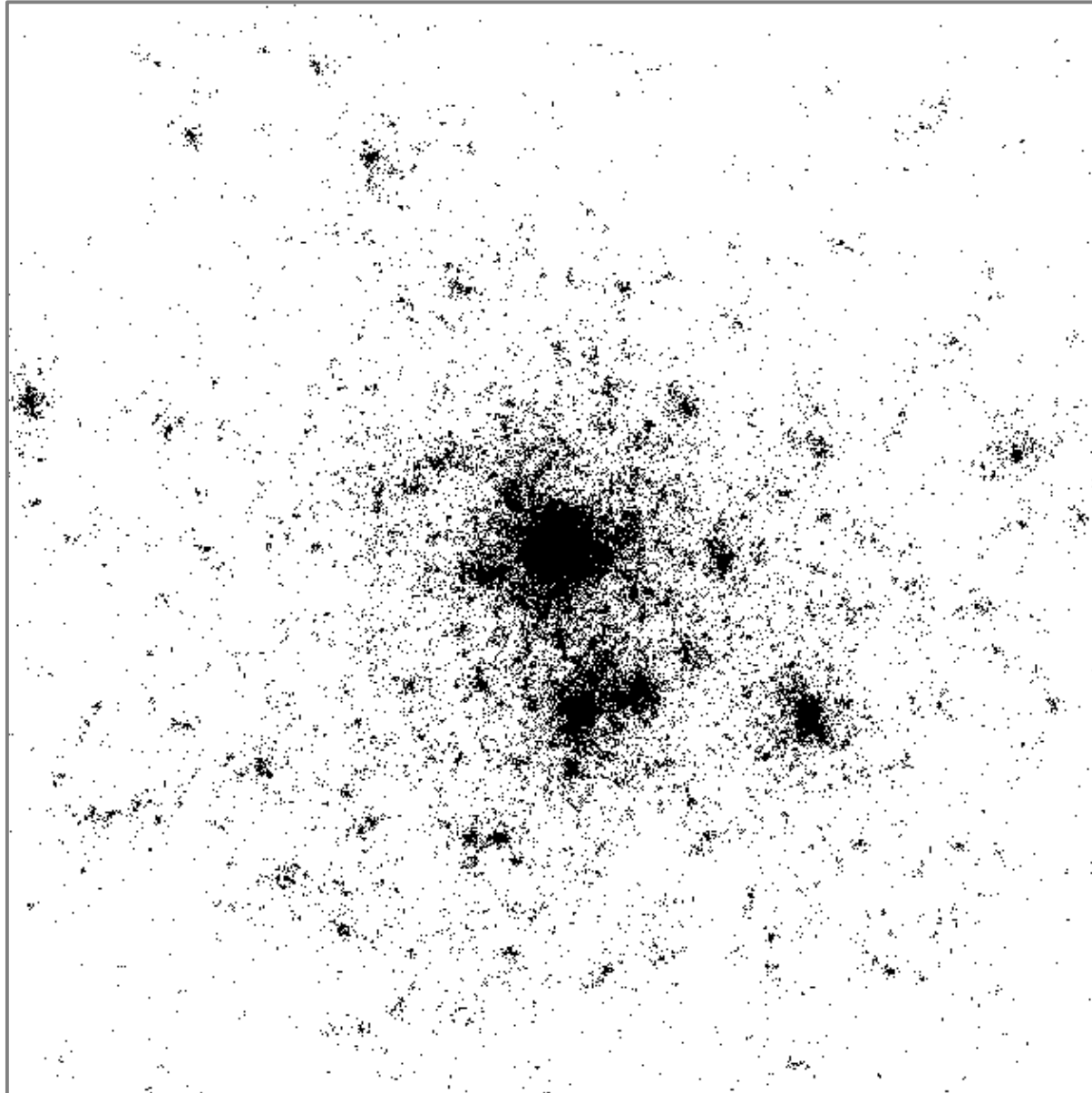
Example
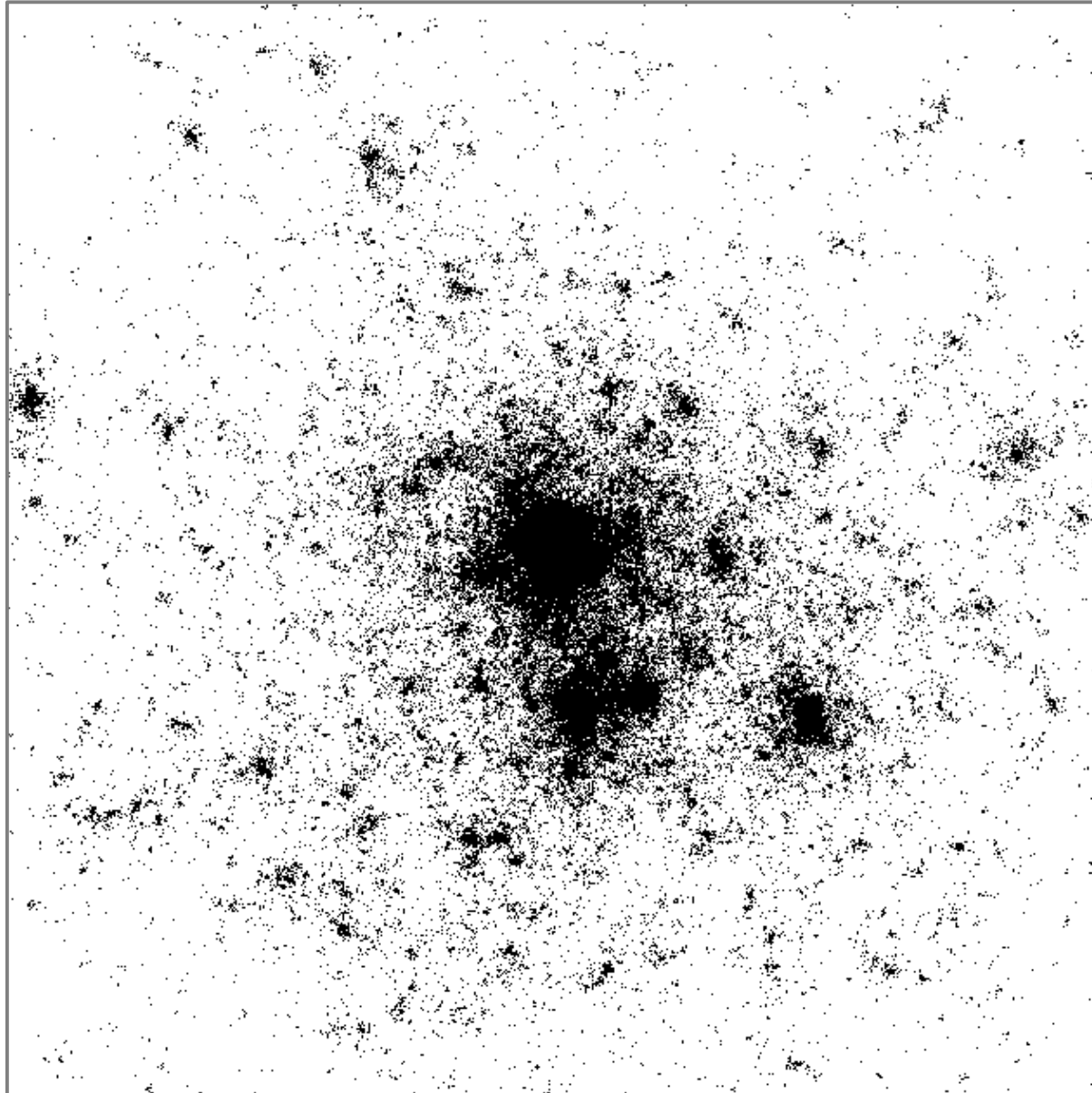
Example
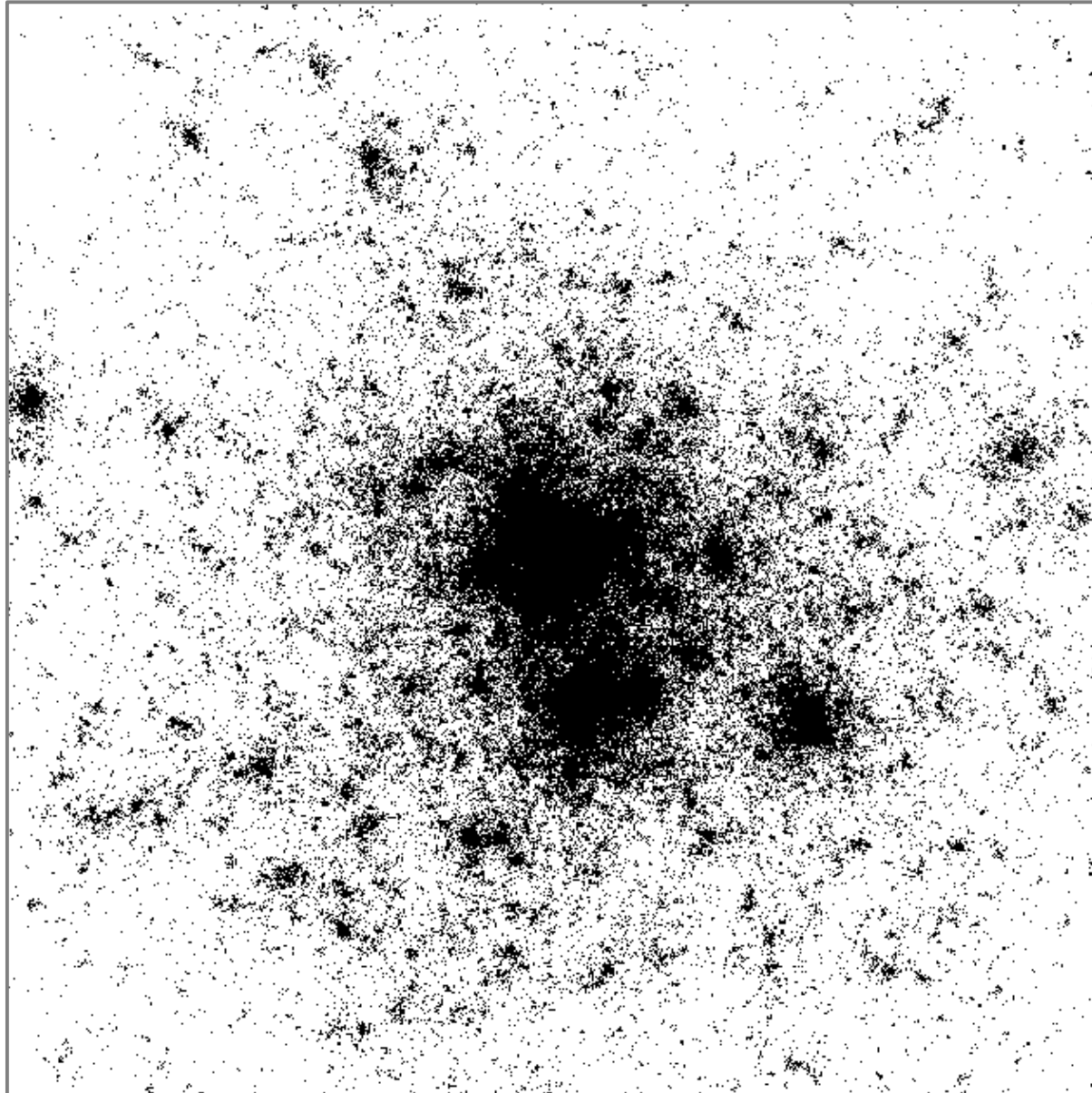
Example
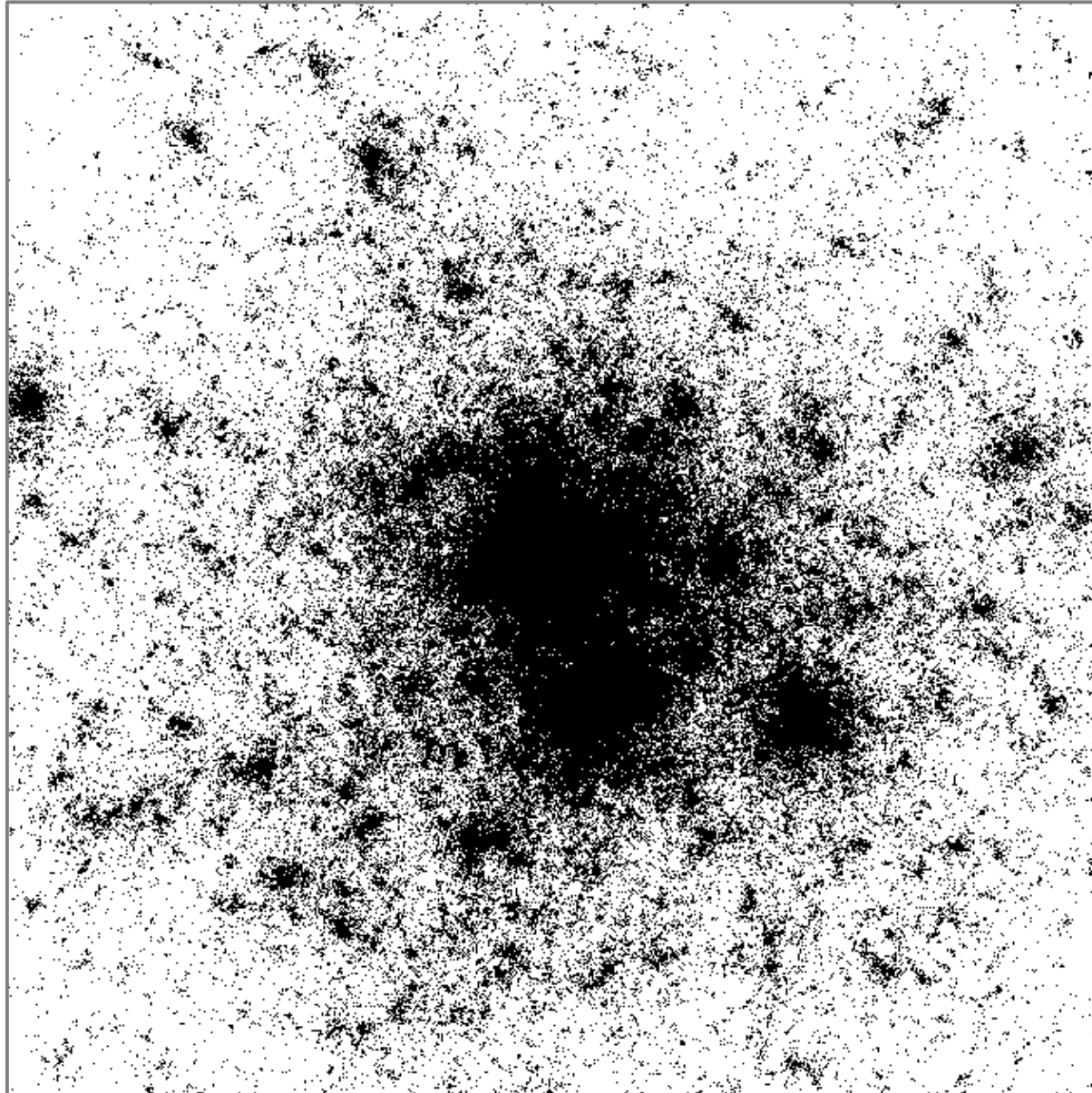
Example
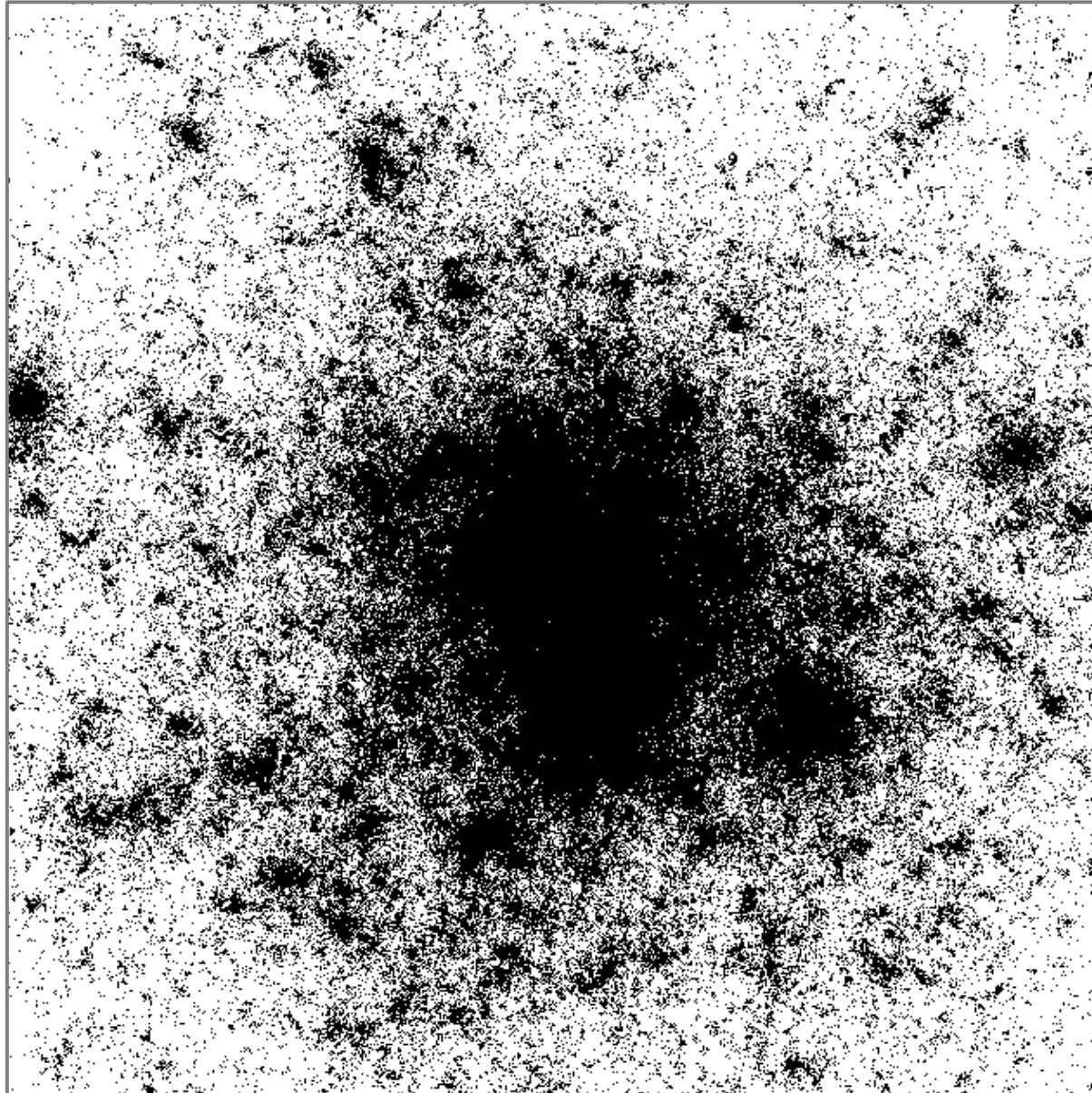
Example

Example

Example .. end

Exponent

γ=1.5 i=2

γ=2.0 i=5
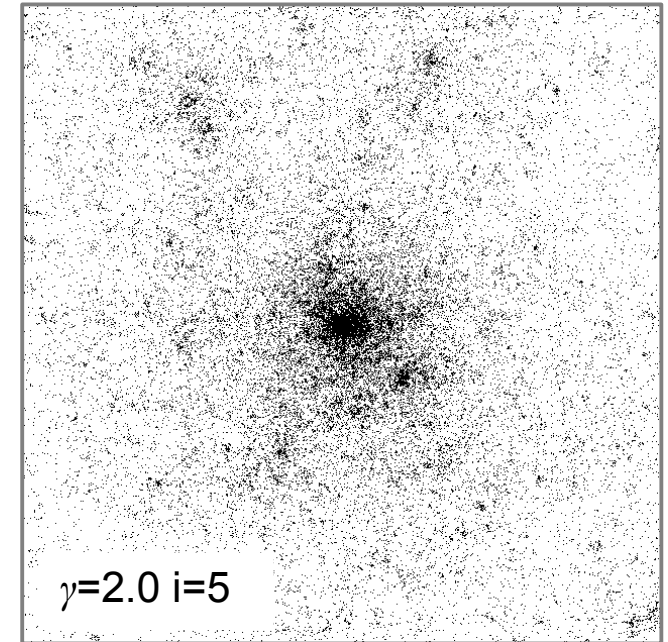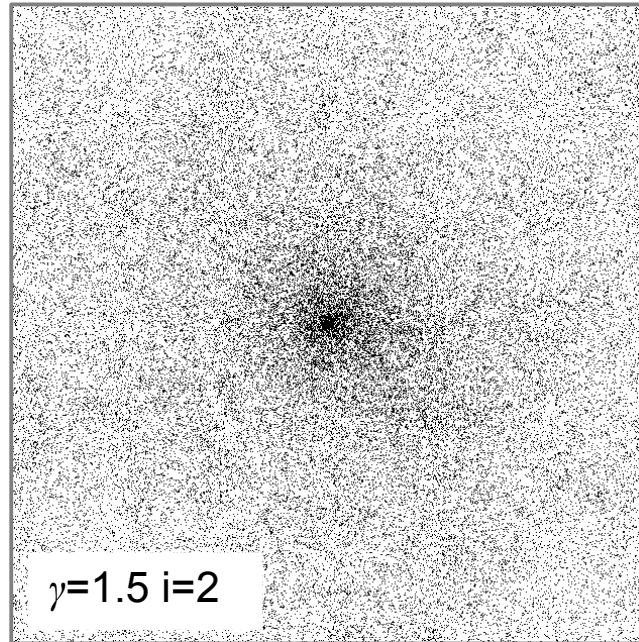
- small exponent
  fills faster

- large exponent
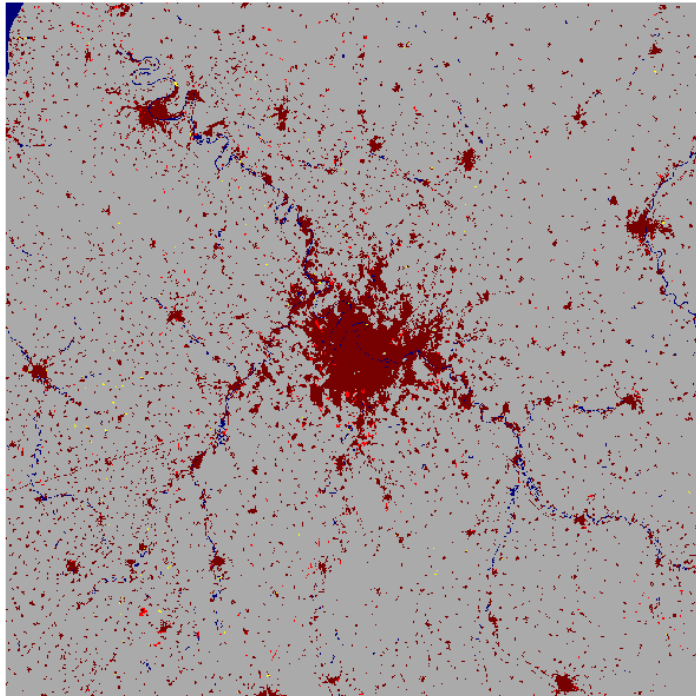 more compact

- large exponent
  less rad. sym.

γ=2.5 i=10

γ=3.0 i=17
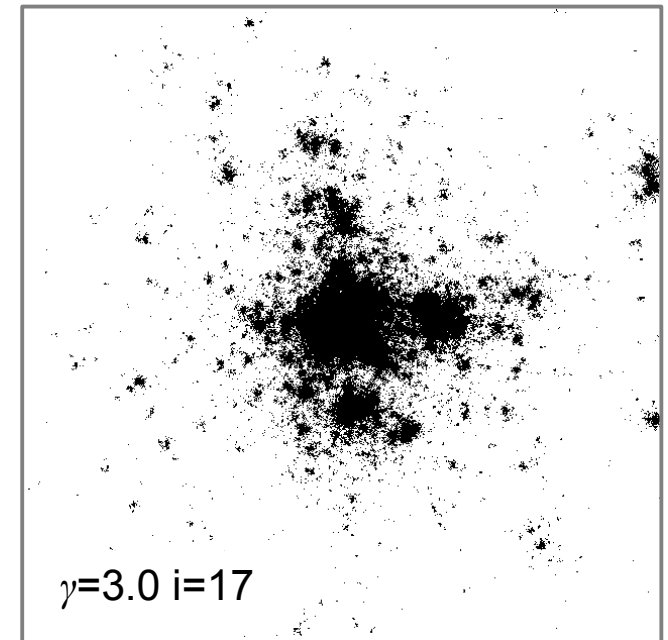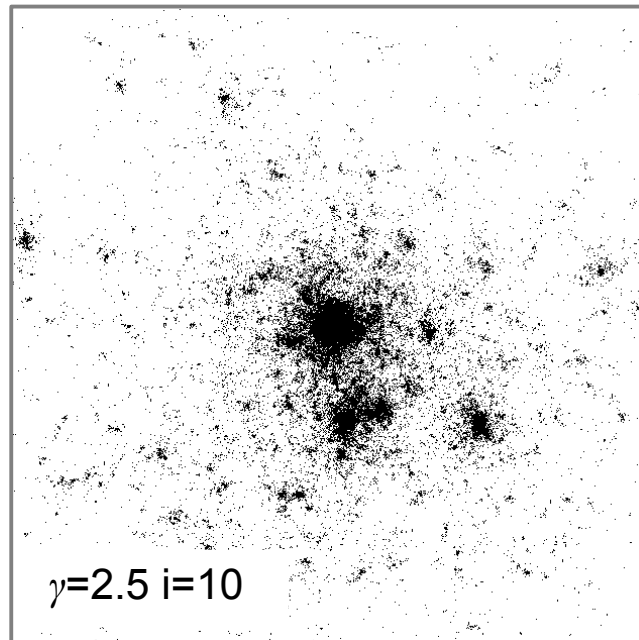
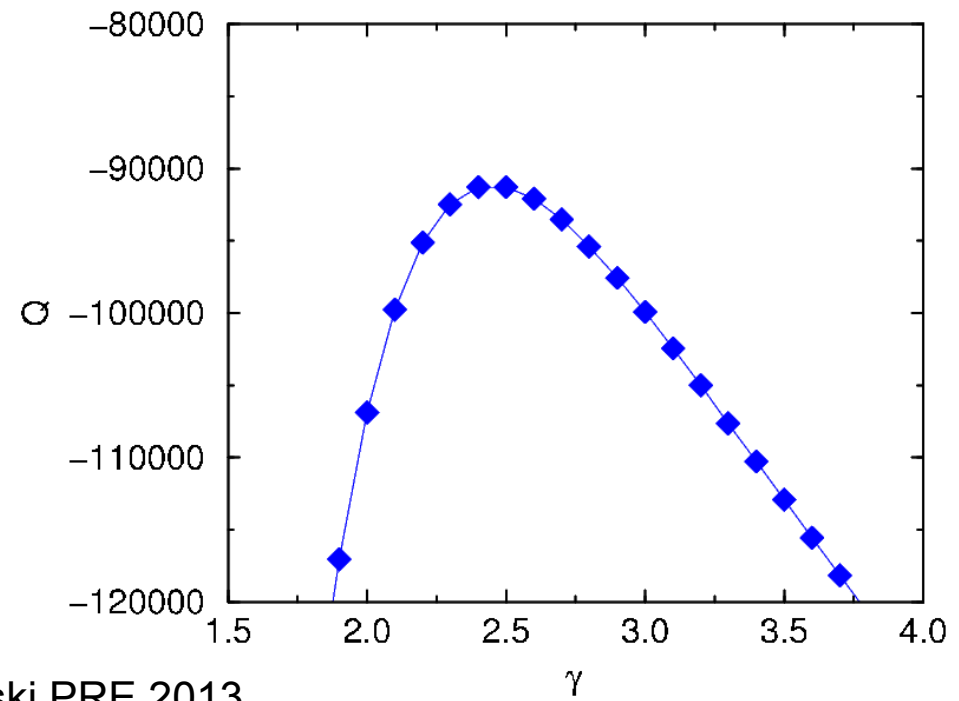# Gravitational city model: benchmarks

(i)   City **size** distribution   partly (excluding largest cluster)

(ii) City **growth**   no

(iii) **Fractality**   yes

Gravitational city model:
Estimating exponent in real data

Rybski PRE 2013

Paris 2000-2006   log-likelihood

Publications (*et al.* are ...)

City Clustering:
city size: H.D. Rozenfeld et al., AER, 2011
city growth: H.D. Rozenfeld et al., PNAS, 2008

Auerbach's legacy:
D. Rybski, Env Plan A, 2013

Gravitational city model:
D. Rybski et al., Phys Rev E, 2013

Urban Heat Island statistics:
B. Zhou et al., Geophys Rev Lett, 2013

Correlations between agricultural GDP and rural population:
R. Lutz et al., Phys Rev E, 2013

This talk:
D. Rybski & J.P. Kropp, in prep., 2014

Ramses project

RAMSES stands for
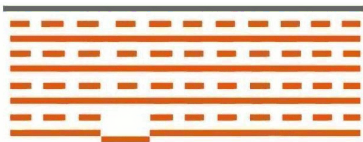**R**econciling **A**daptation, **M**itigation and **S**ustainable
Development for citi**ES**

The main aim of this research project is to deliver much needed quantified evidence of the impacts of climate change and the costs and benefits of a wide range of adaptation measures, focusing on cities. RAMSES will engage with stakeholders to ensure this information is policy relevant and ultimately enables the design and implementation of adaptation strategies in the EU and beyond. The project will focus on climate impacts and adaptation strategies pertinent to urban areas due to their high social and economic importance.

http://www.ramses-cities.eu/

Thank you for your attention

http://diego.rybski.de/

http://www.pik-potsdam.de/members/rybski/