Continuous time microsimulations for COVID 19

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Types of epidemic models

- Differential equation models (ODE, PDE, stochastic visions)
- Agent based models/microsimulations
- Statistical forecast models (time series , machine learning, AI)

Aim of epidemic microsimulation models

Forecasts

- Short time forecast < 4 weeks
- Scenario forecast: several months

Effect of intervention scenarios

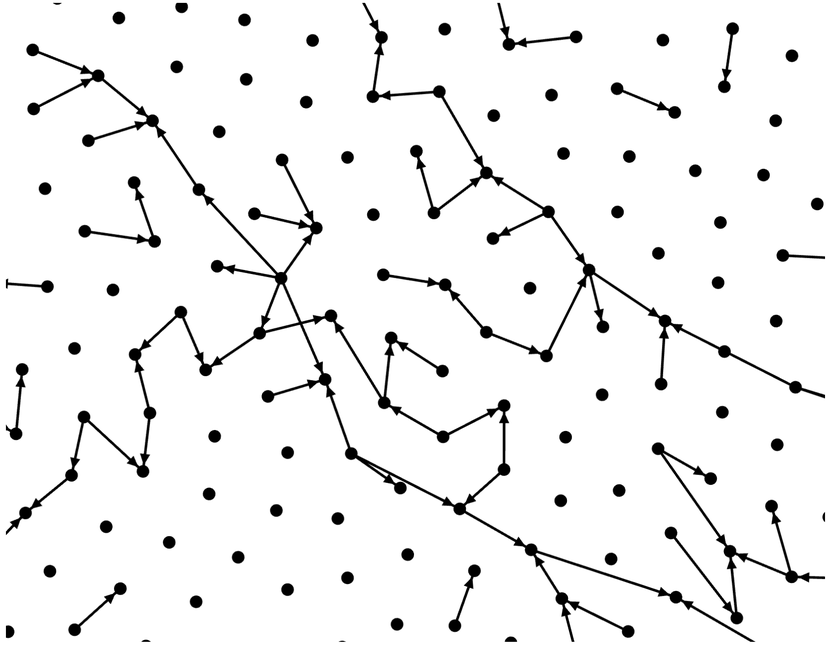
- Non-pharmaceutical interventions: testing, contact tracing, contact restrictions, quarantine
- Vaccination

Structural insights

- Identifying structural socio- economic risk factors
- Impact and estimation of key medical parameters

Microsimulations for epidemic processes

- Most agent based models use discrete time (in epidemics 1 day)
- Network of agent-type, space and time dependent contacts is a basic structural component for all agent based epidemic models
- For simulations it is enough to consider the infection subgraph (edges represent only infectious contacts)
- Complex intervention measures can only be represented in agent based microsimulations



Infection graph is a subgraph of the contact graph

MOCOS microsimulation:

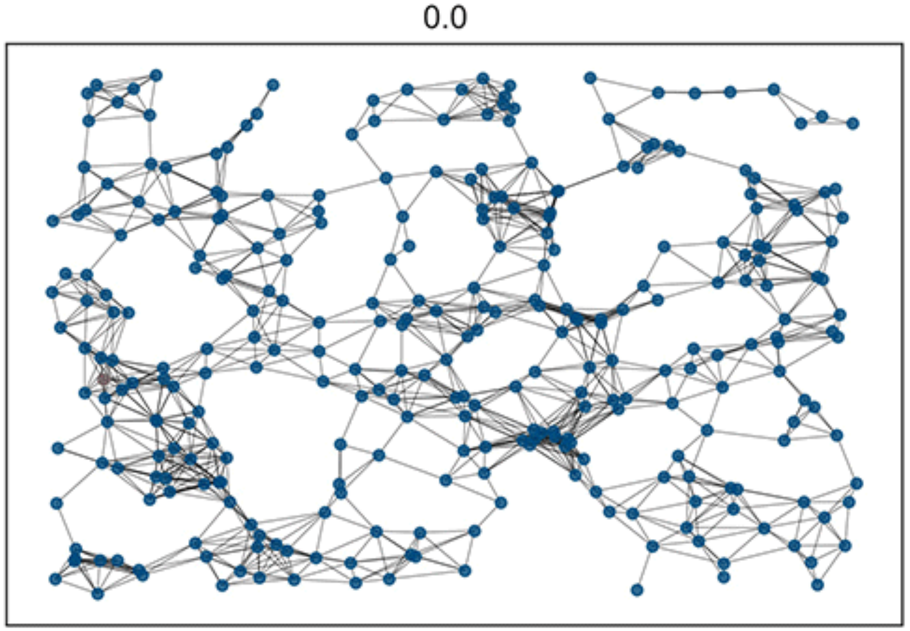
continuous time setting is a natural framework for infection events and disease progression

- Event driven microsimulation model of COVID 19 epidemics
- Continuous-time distributions of disease progression
- Random and heterogeneous structure of intra-household and out-household contacts
- intervention measures:

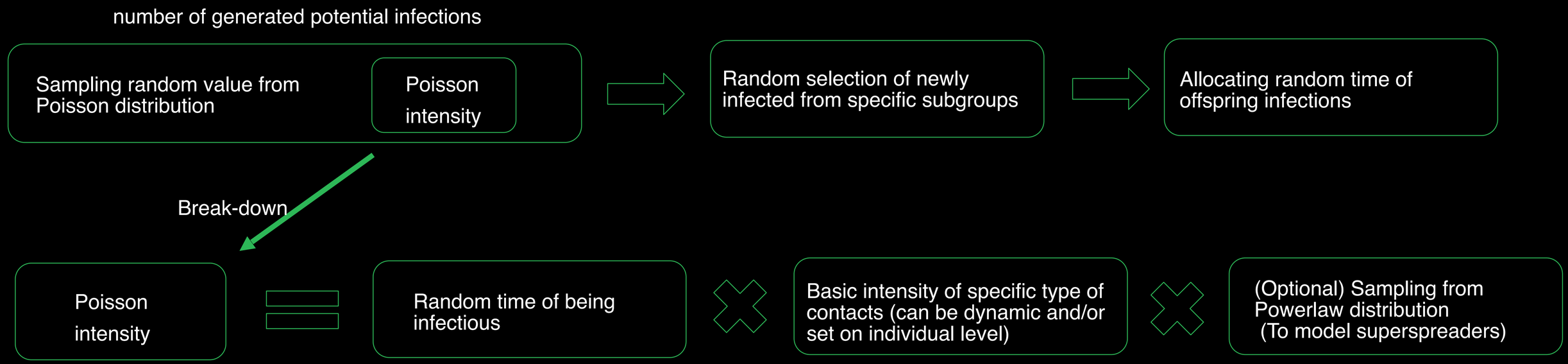
  quarantine, targeted testing, contact tracing, contact reduction, contact tracking app

MOCOS - microsimulation network structure

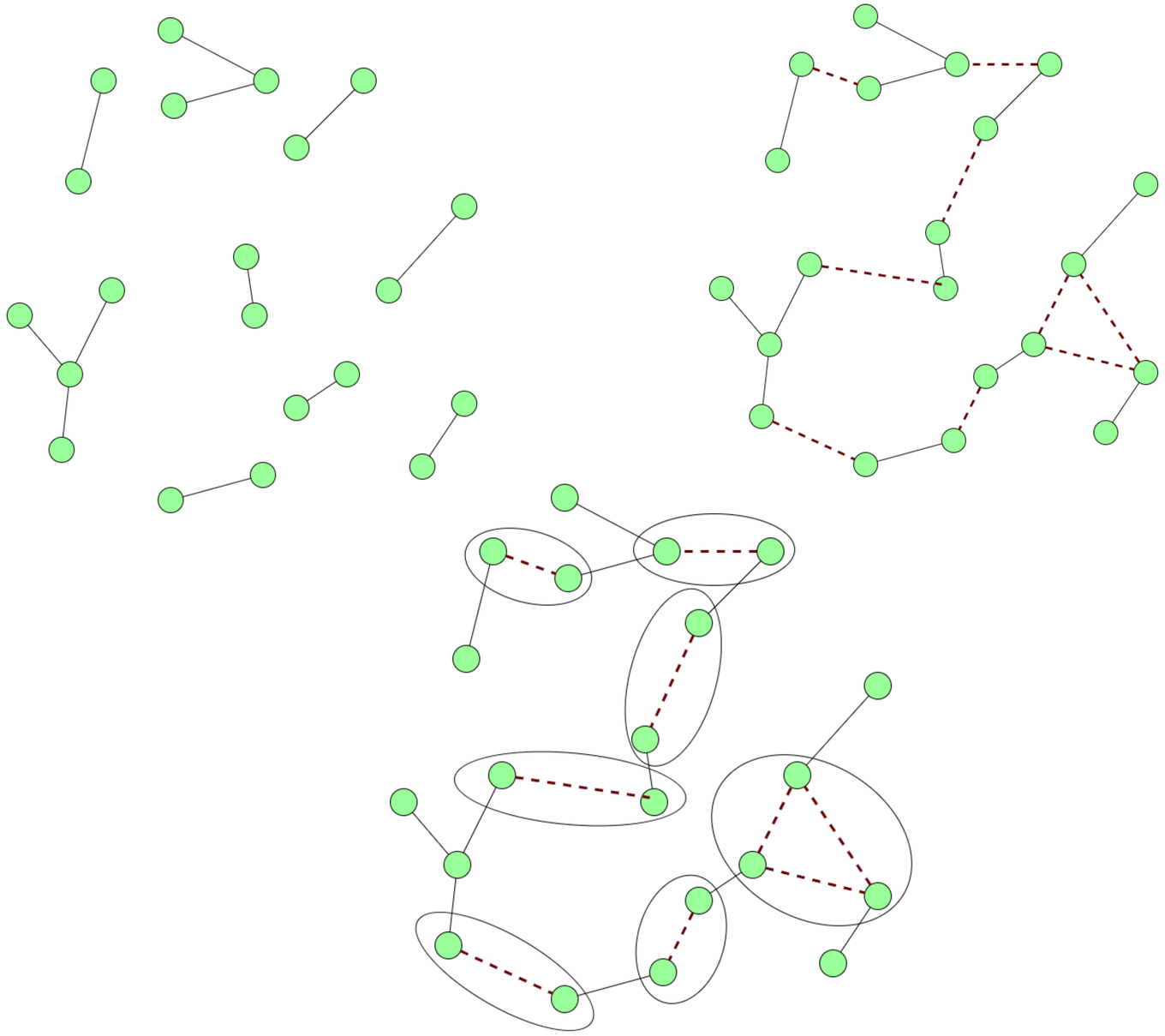
- Assign feature vector x to each individual
- Contact kernels K (x, y) describe the likelihood of infectious contact between type x and type y individual
- Precomputed timing of individual disease progression is part of feature vector
- Contact network is superposition of specific contact structures like workplace, travel , shopping , school , hospitals, households..

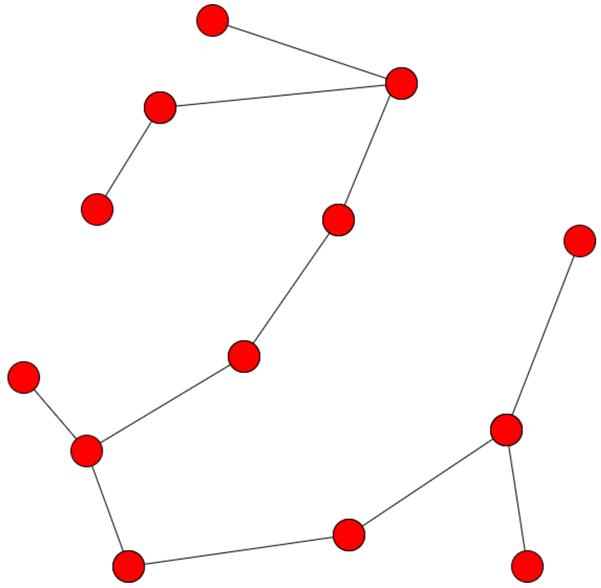


Flow chart : Generating new infected individuals



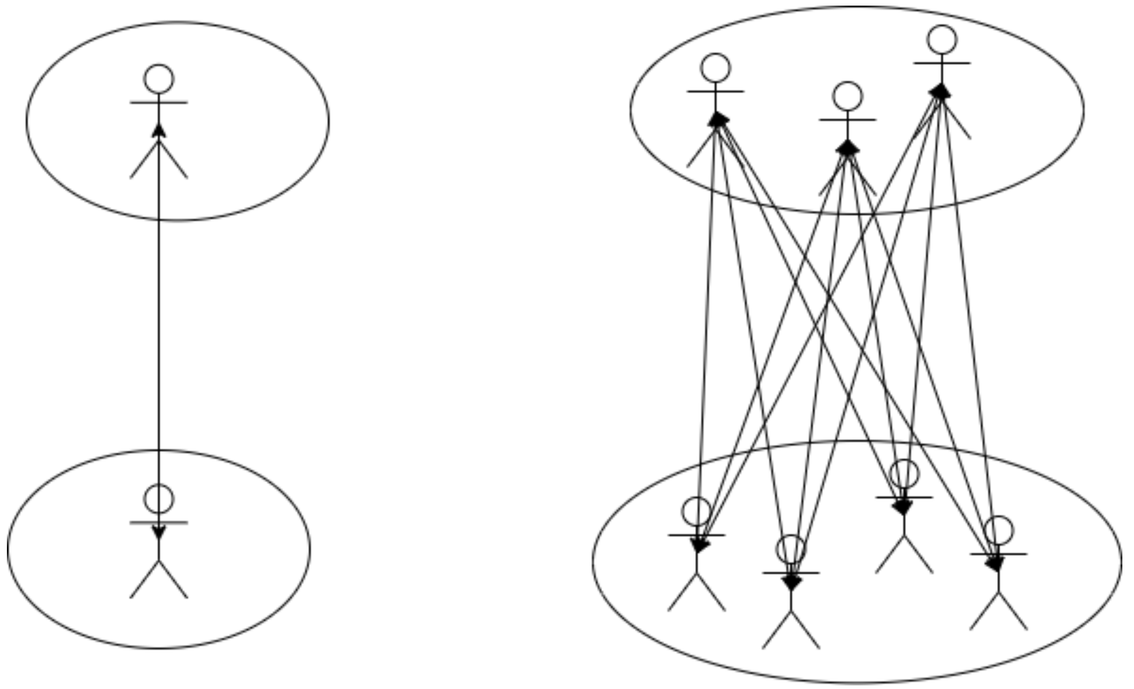
Structural insights: Households are a key factor for epidemic dynamics





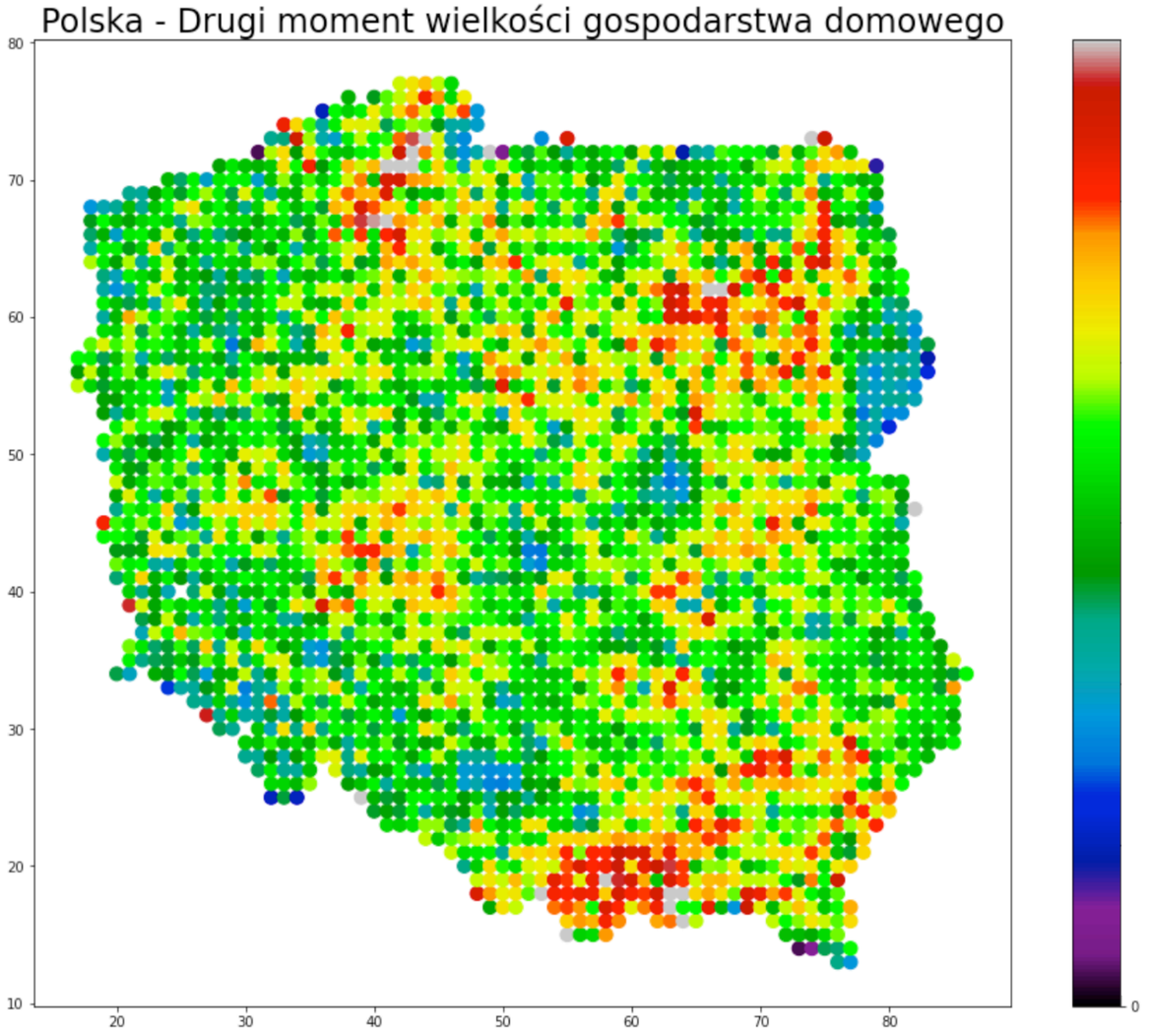
From network between individuals to network between households

Large households have catalytic effect on the spread because link probability between two households is proportional to the product of their sizes

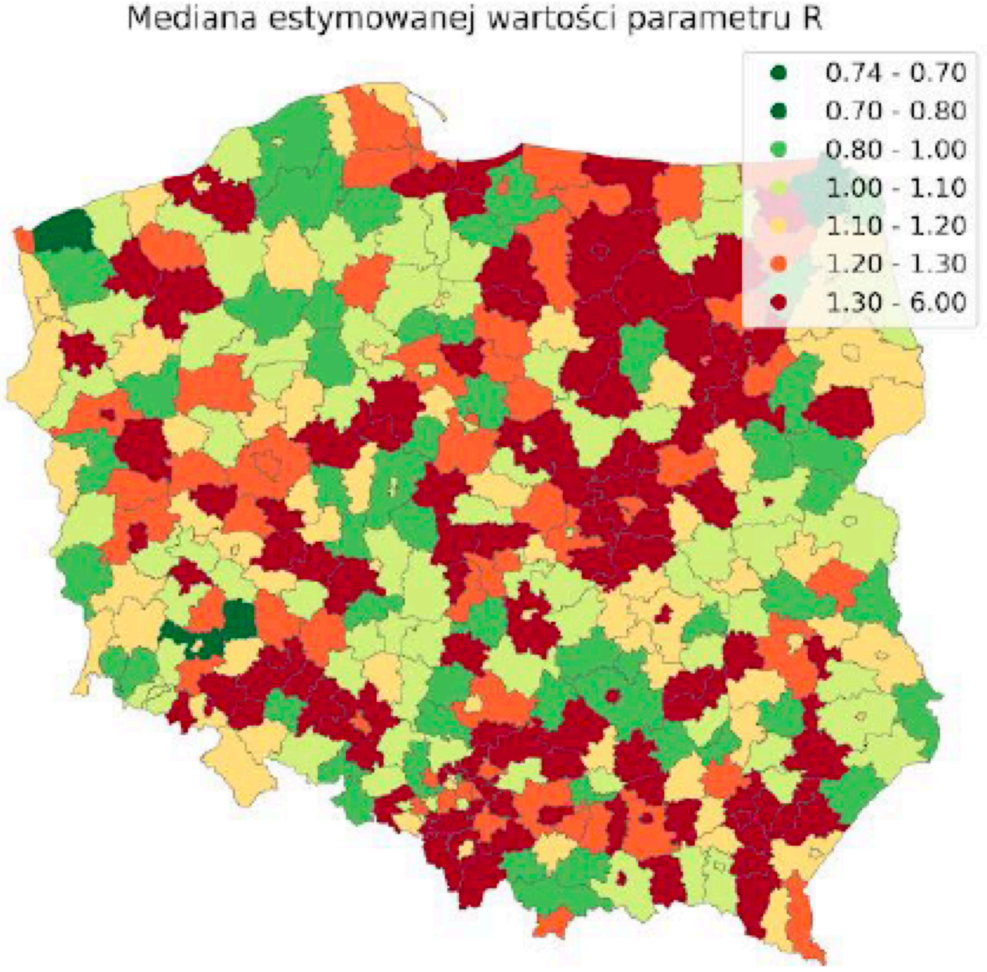


Microsimulations show: Large households are a structural risk factor for epidemic spread

Second moment of household size distribution of Poland on 10x10 km grid

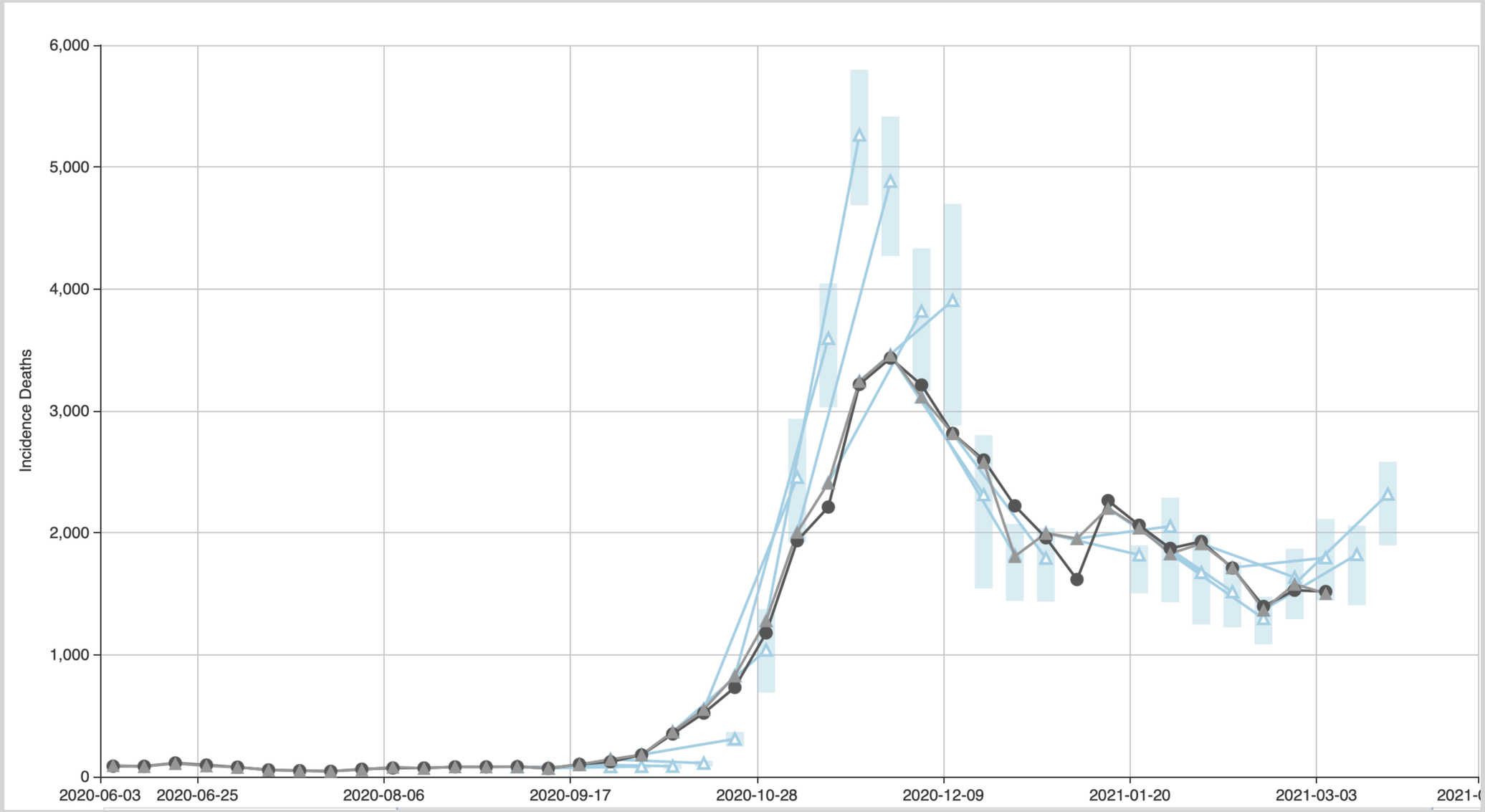


Estimated reproduction number on county level Poland (end of February 2021



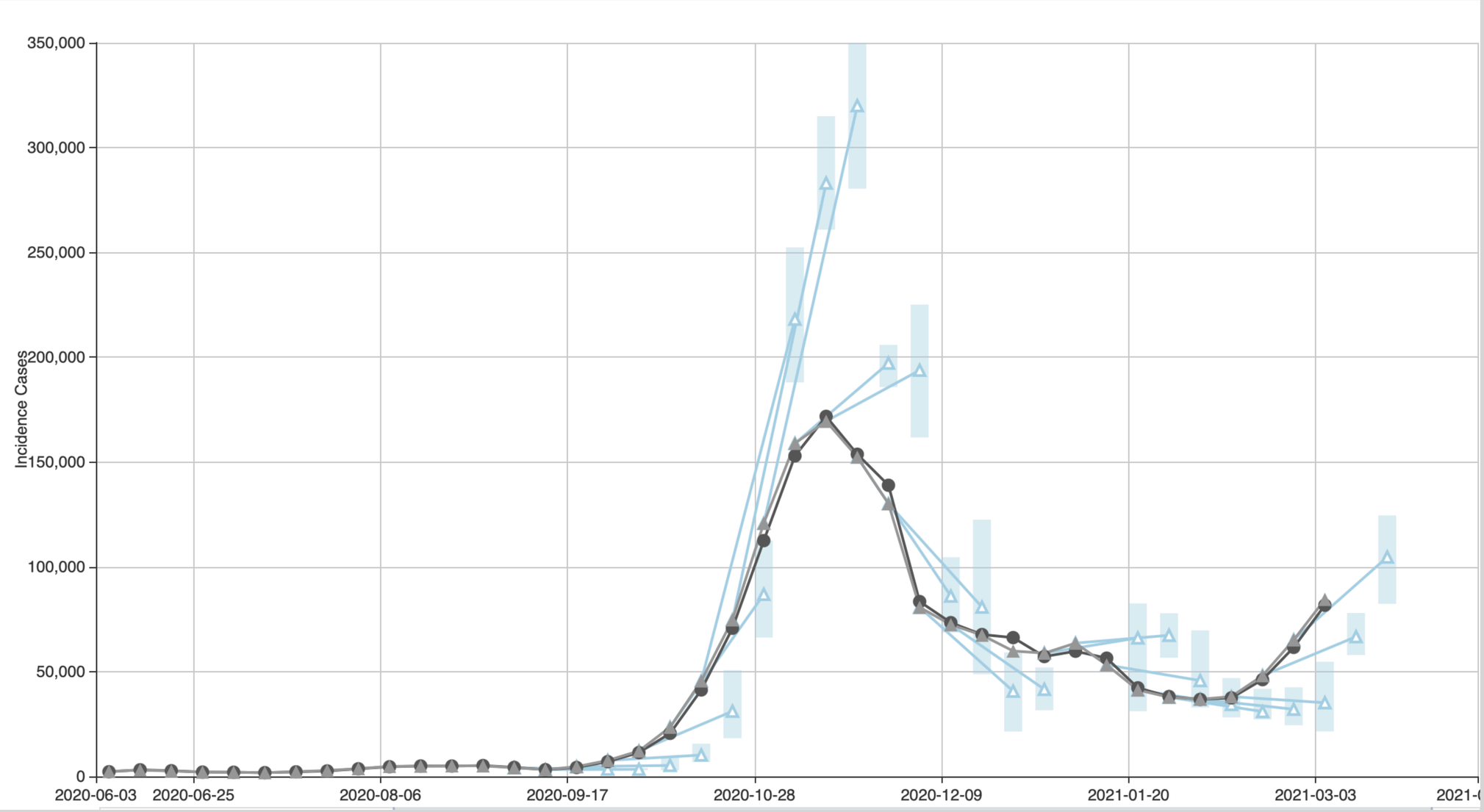
Model Output : 3 week predictions death Poland

(50% confidence band)



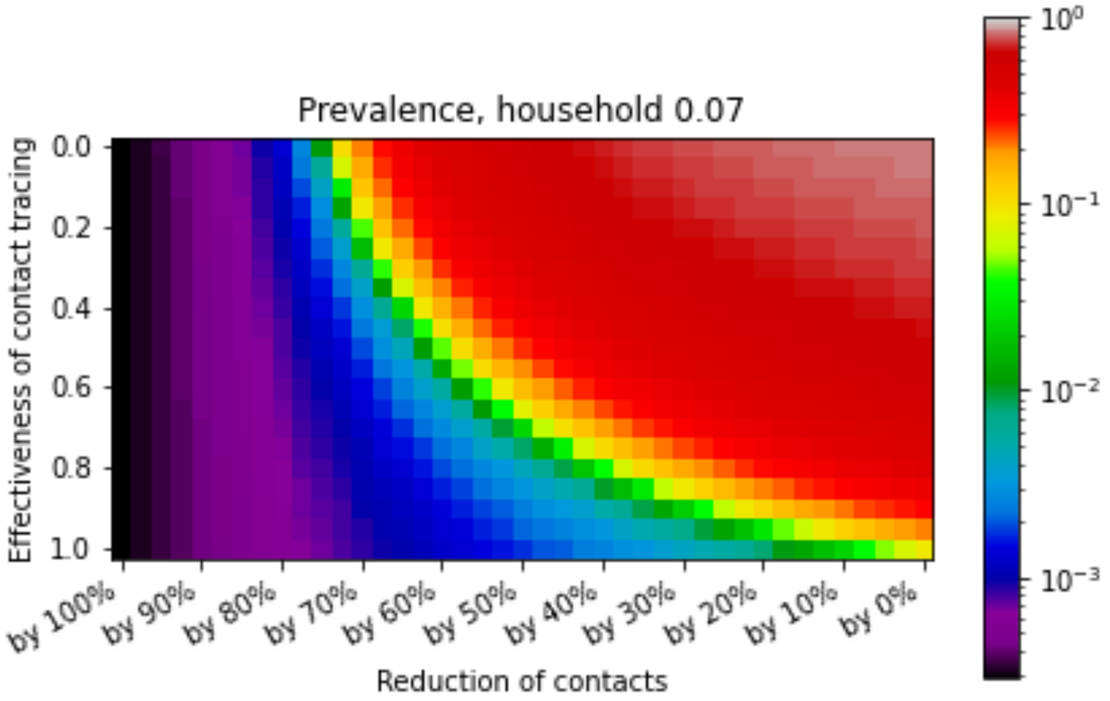
Model Output : 3 week predictions incidence cases

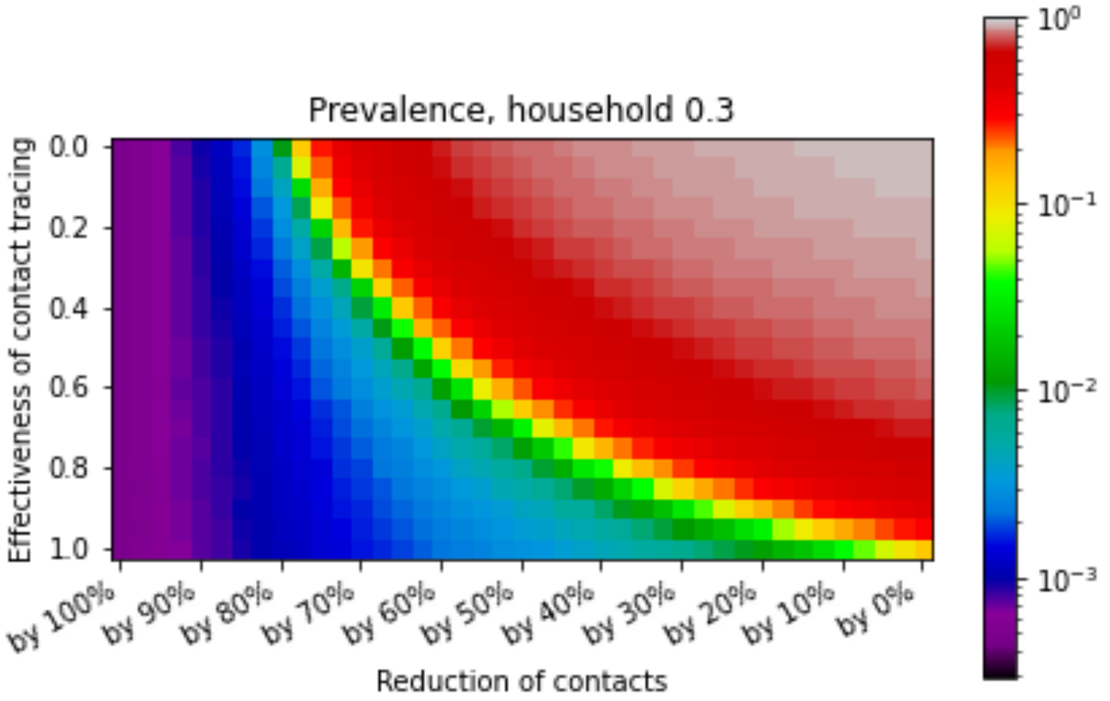
(50% confidence band)



Model Output: structural heat maps (Poland)

Prevalence in dependence of restrictions and tracing efficiency



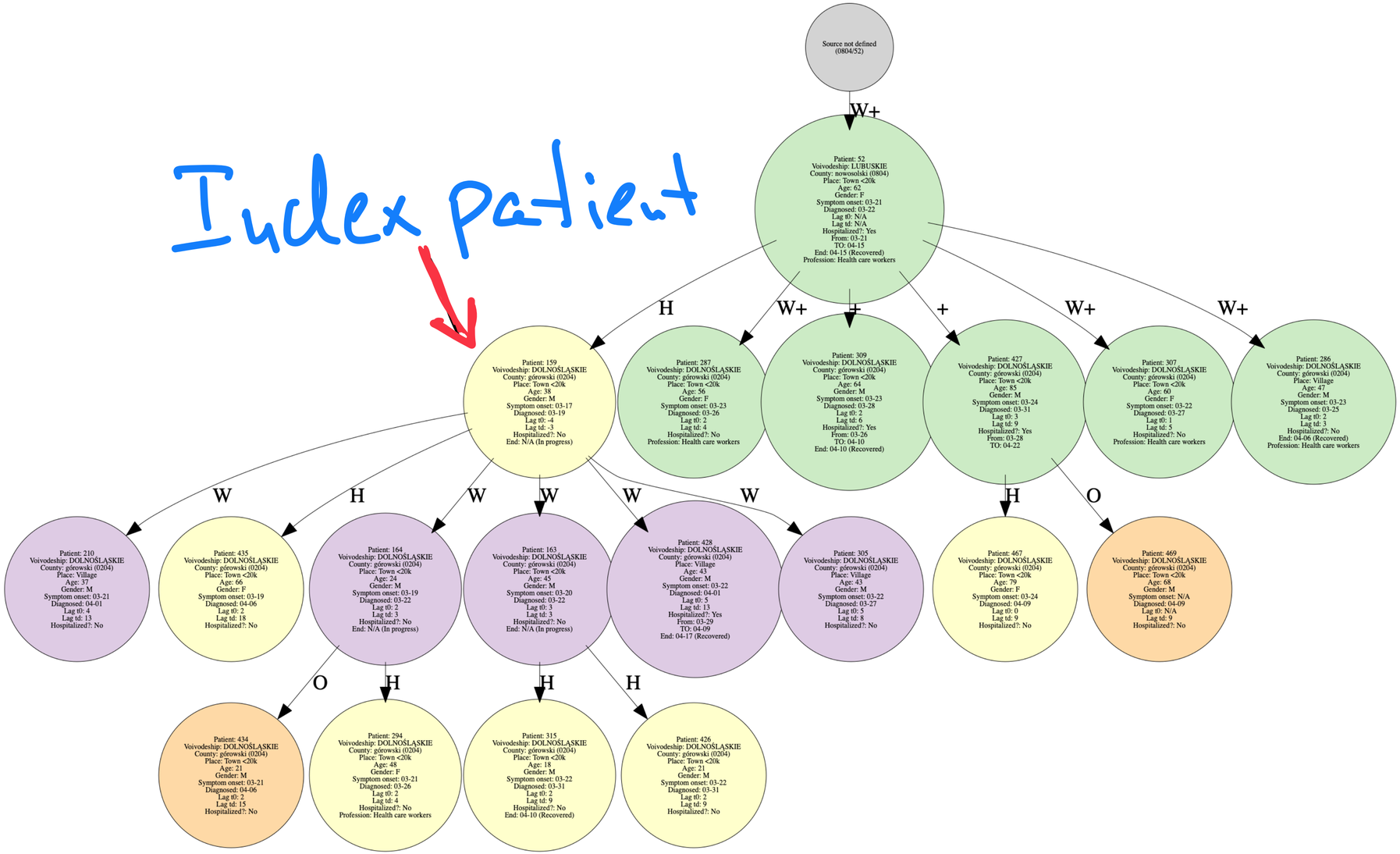


Data needs for epidemic microsimulations

- Census data used to generate sample population
- Medical data: polish patient data and medical databases
- network of contacts (special polls like POLYMOD)
- Contact tracing and testing: linked patients data
- Mobility data: relevant for long distance contacts

Most of above data in very poor quality !

Linked patient data allow to estimate efficiency of testing and tracing



- Whole time to detect the cluster took 19 days
- Novel statistical techniques needed for extracting relevant key parameters of contact tracing and testing

The MOCOS group

- Our research focuses on a) agent based modelling of the COVID 19 pandemic, b) analysis of patient data and c) mathematical model analysis
- Interdisciplinary collaboration of scientists across the world
- MOCOS group is part of the external adviser team for polish ministry of health
- MOCOS group is closely cooperating with city of Wroclaw administration and provides regional risk analysis
- MOCOS group is part of the SaxoCov project and responsible for agent based modelling of COVID 19 for the german state of Saxony