Emergent Behaviour - Theory and Experimentation using the MANA model

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Can *emergent behaviour* in MANA be represented by a *metamodel*?

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Outline

- Introduction
- Theory and Experimental Evidence
  - Kill probability and mean casualty rate
  - Casualties over time
- Conclusions
- Way forward

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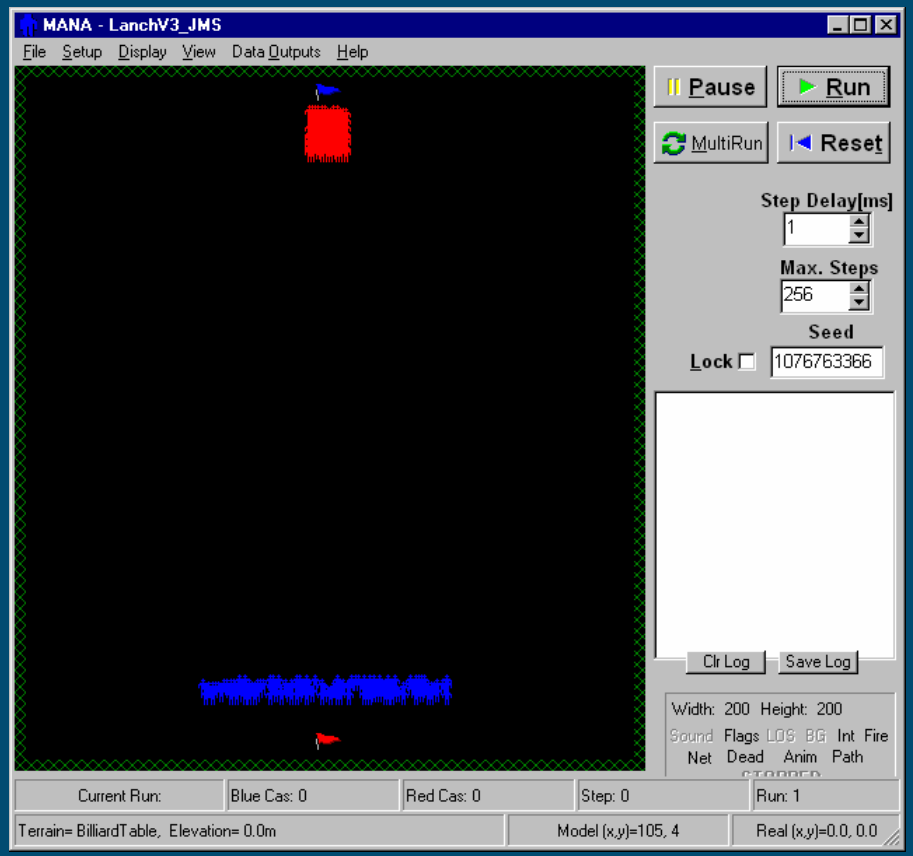
Introduction

- MANA and complexity
  - **M**ap-**A**ware **N**on-uniform **A**utomata
- International collaborations
  - TTCP JSA TP3
  - Project Albert



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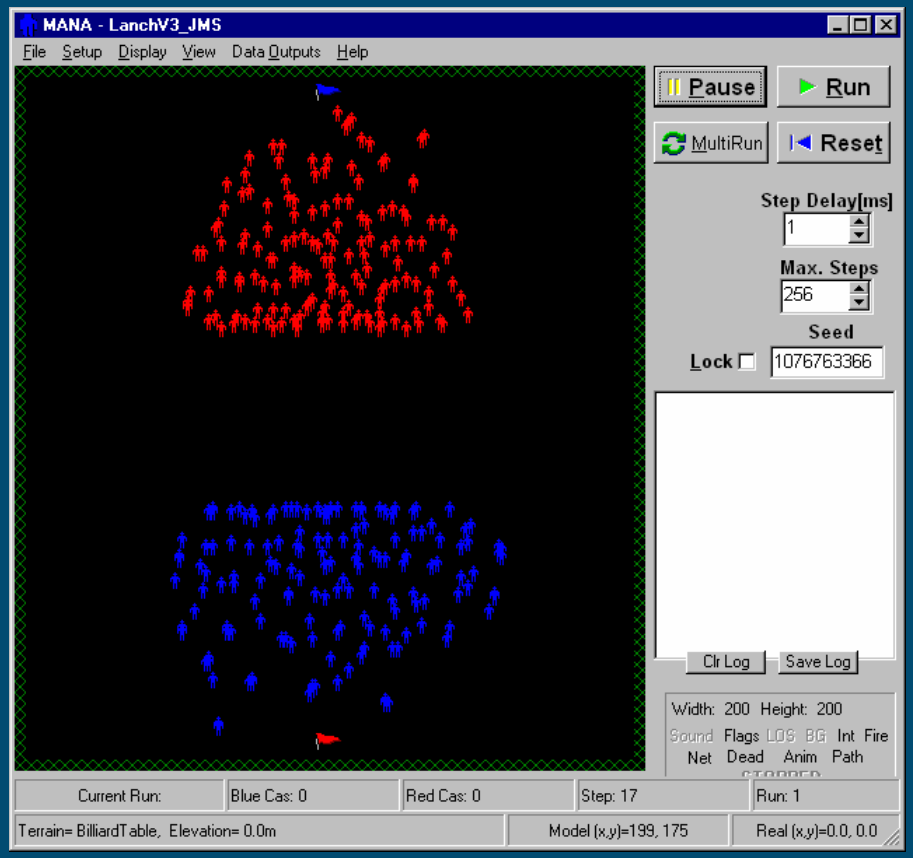

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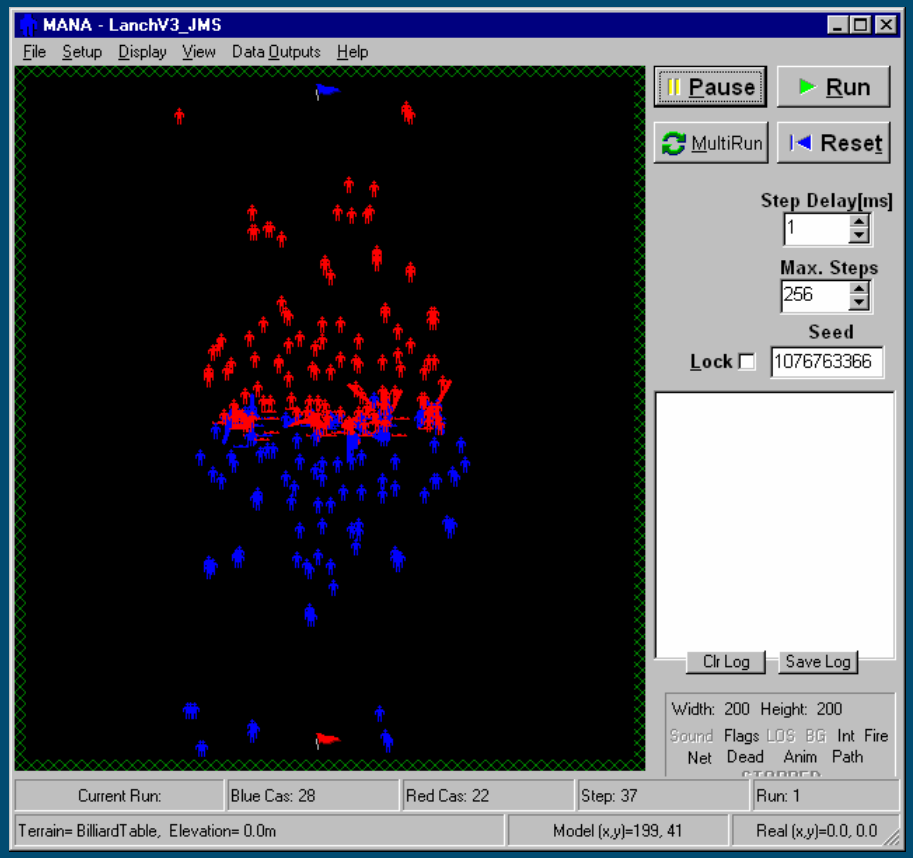

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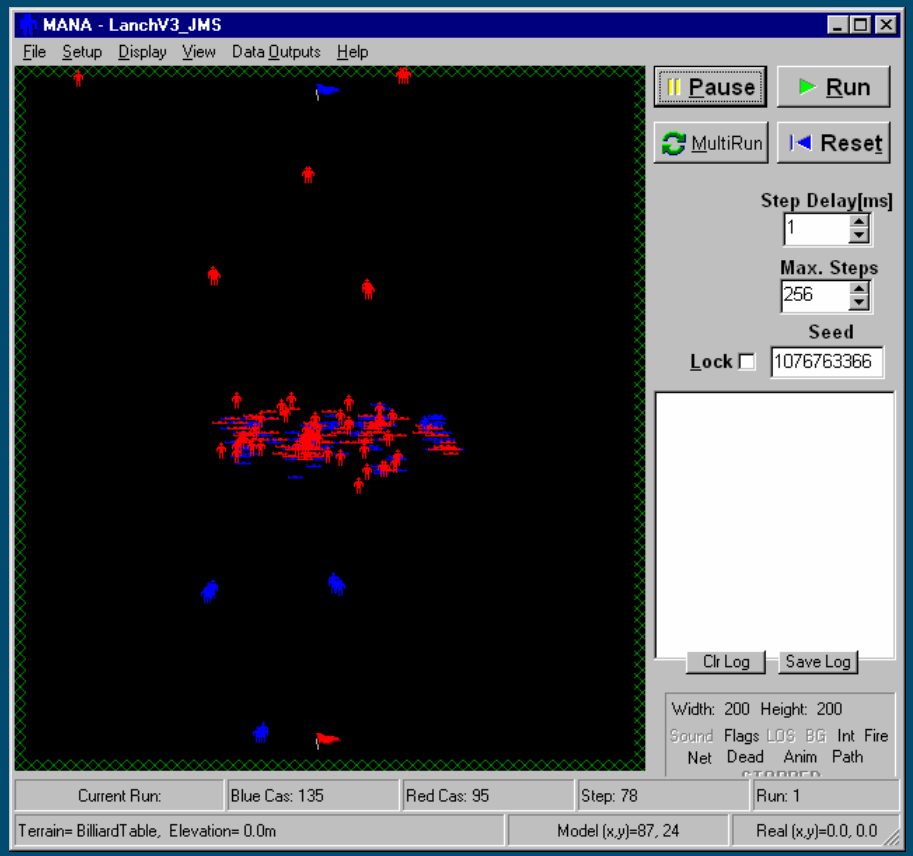

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Our theory: the Metamodel

$$E\left(\left|\frac{\Delta B}{\Delta t}\right|\right) = k^{q(D)}\Delta t^{-r(D)}N(t)\overline{\varphi}(x,t)$$

Blue Casualty rate

Individual red agent effectiveness

Red Fractal Dimension

Time period

Number of Red Clusters

Average Red cluster size

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Our theory: the Metamodel

The first term

$$E\left(\left|\frac{\Delta B}{\Delta t}\right|\right) = k^{q(D)}\Delta t^{-r(D)}N(t)\overline{\varphi}(x,t)$$

Blue Casualty rate

Individual red agent effectiveness

Red Fractal Dimension

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Number of Red Clusters

Average Red cluster size

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First term: Theory

$$E\left(\left|\frac{\Delta B}{\Delta t}\right|\right) \propto k^{q(D)}$$

Blue Casualty rate

Individual red agent effectiveness

Red Fractal Dimension

Take logarithms

$$\log E\left(\left|\frac{\Delta B}{\Delta t}\right|\right) = q(D)\log k + c$$

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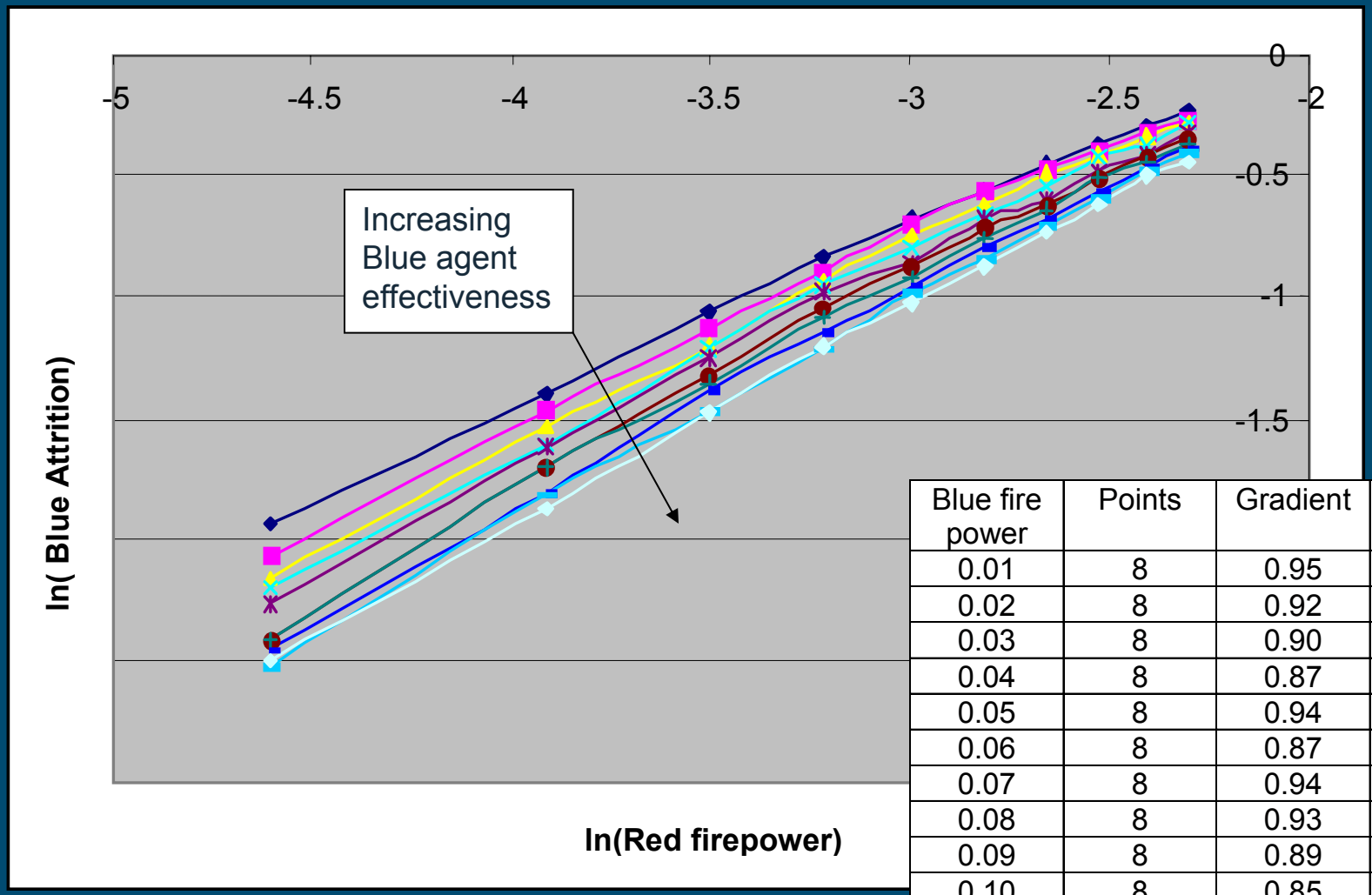
First term: Meet Scenario data



Blue fire power	Points	Gradient	Intercept
0.01	8	0.95	0.73
0.02	8	0.92	0.62
0.03	8	0.90	0.54
0.04	8	0.87	0.46
0.05	8	0.94	0.67
0.06	8	0.87	0.50
0.07	8	0.94	0.68
0.08	8	0.93	0.61
0.09	8	0.89	0.50
0.10	8	0.85	0.37

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Our theory: the Metamodel

The second term

$$E\left(\left|\frac{\Delta B}{\Delta t}\right|\right) = k^{q(D)}\Delta t^{-r(D)}N(t)\overline{\varphi}(x,t)$$

- Blue Casualty rate
- Individual red agent effectiveness
- Red Fractal Dimension
- Time period
- Number of Red Clusters
- Average Red cluster size

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Second term: Theory

$$E\left(\left|\frac{\Delta B}{\Delta t}\right|\right) \propto \Delta t^{-r(D)}$$

Multifractal statistics

$$P_{B_t}(f) \propto |f|^{-(D+1)}$$

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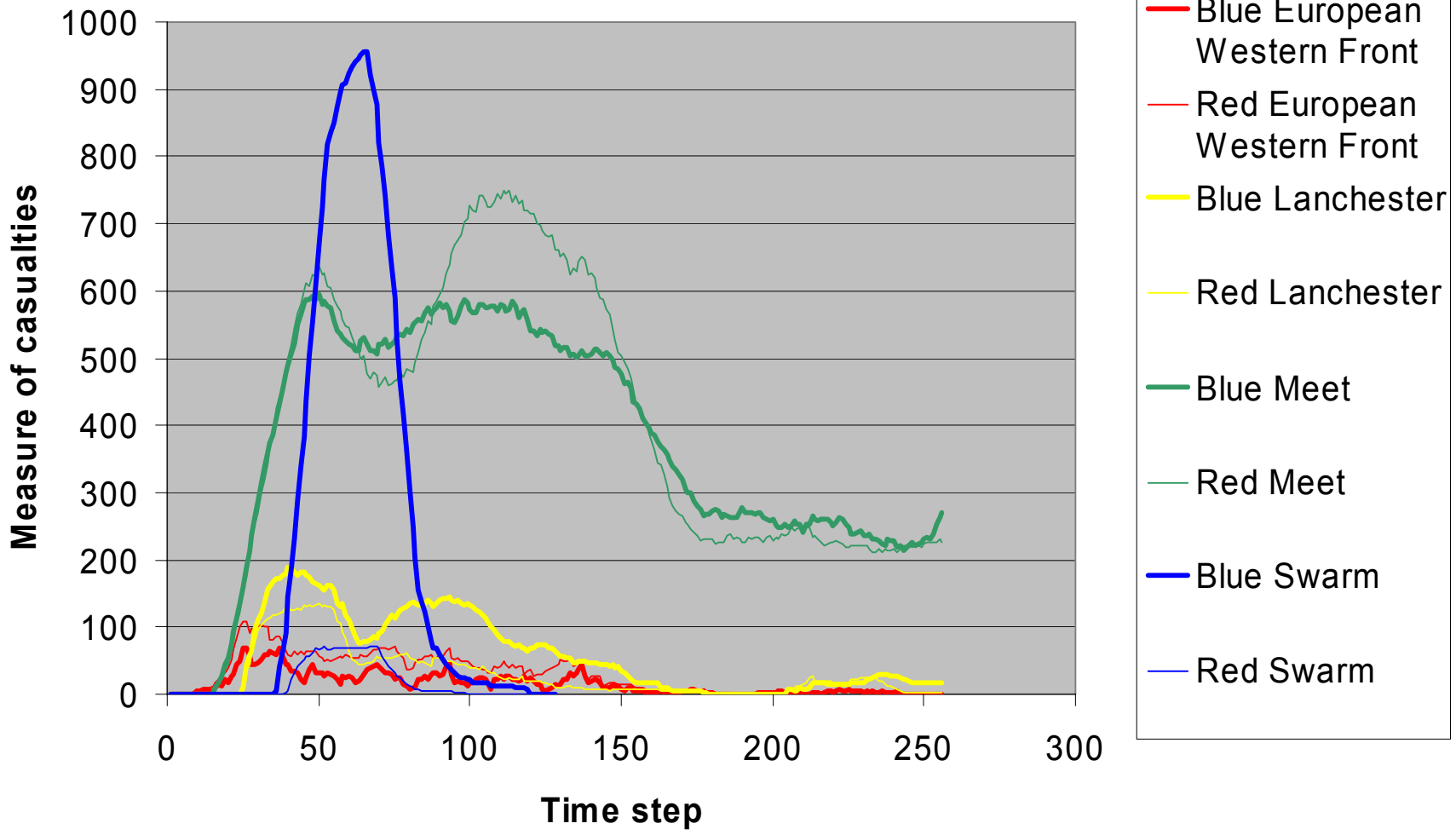
Second term: example MANA data



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Second term: Theory

- Analysis tool:

  for $j = 0, 1, 2, \ldots, N$

$$P_{B_t}(f_j) = \left| \sum_{t=0}^{t=N} B_t e^{2\pi i j t / N} \right|^2$$

- Expected result

Take logarithms

$$P_{B_t}(f) \propto |f|^{-(D+1)} \quad \rightarrow \quad \log P_{B_t}(f) = -(D+1)\log|f| + c$$

$$D \in [0, 2] \quad \rightarrow \quad -(D+1) \in [-3, -1]$$

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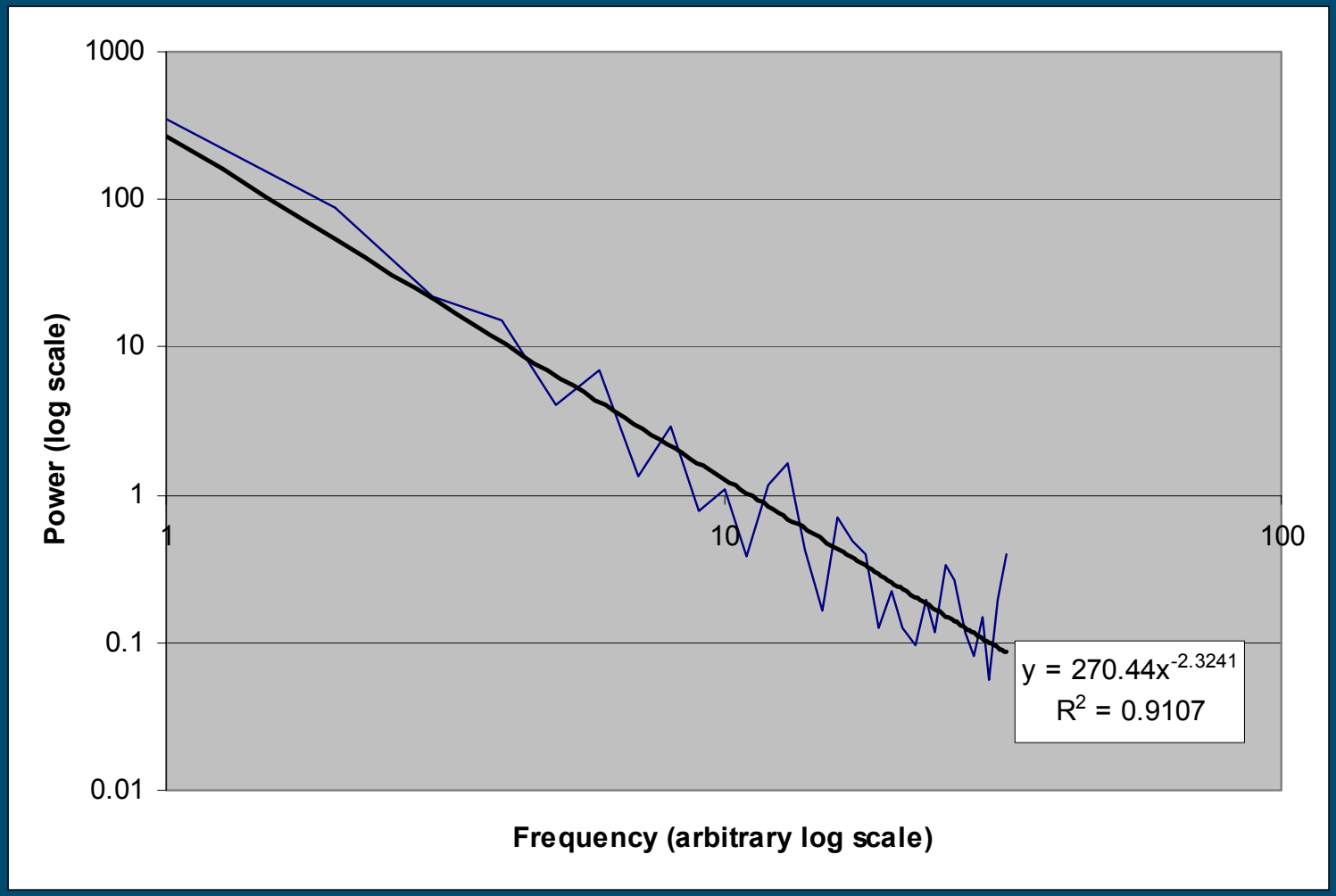
Second term: Euro West Front data



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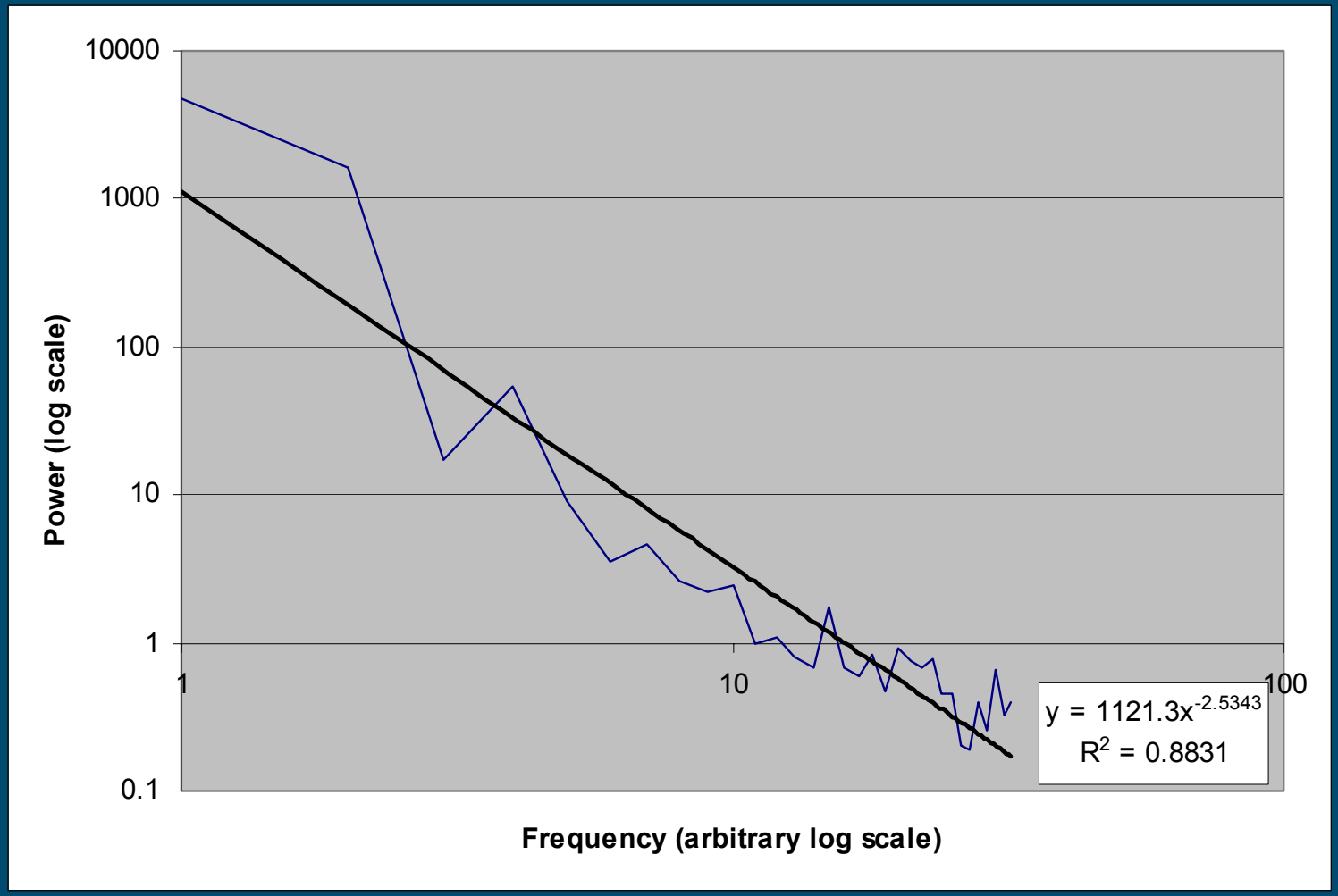
Second term: Lanchester data



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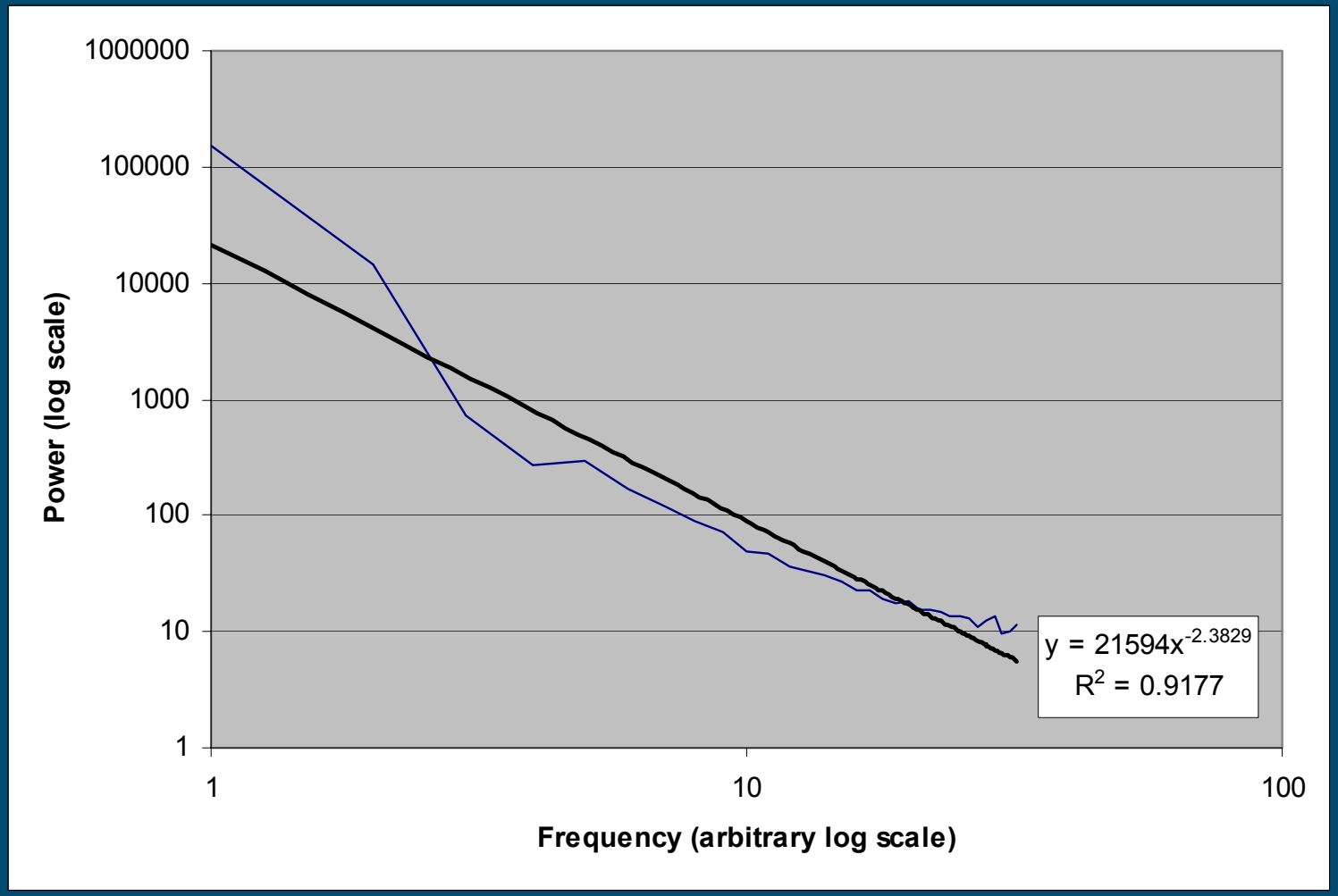
Second term: Meet data



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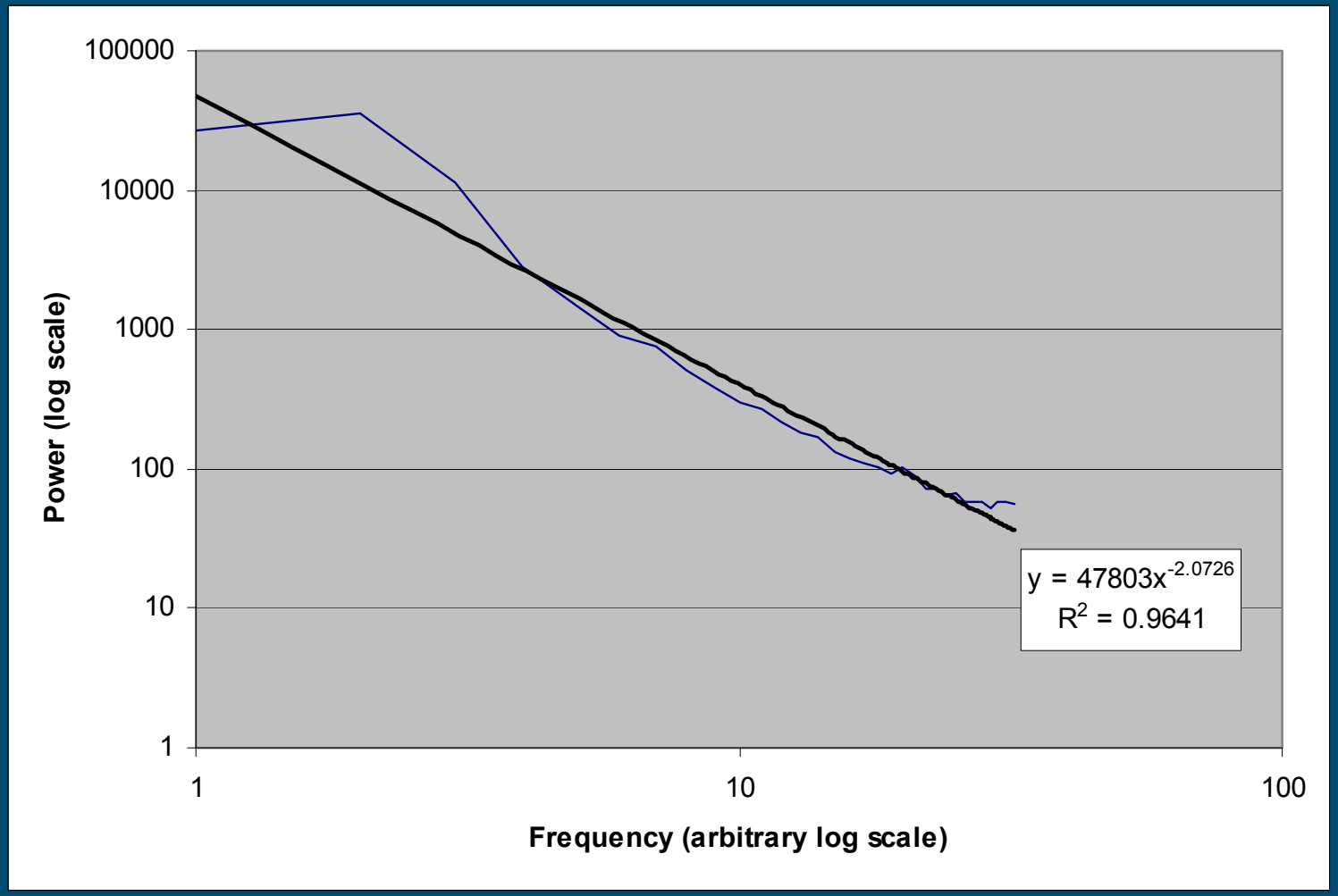
Second term: Swarm data



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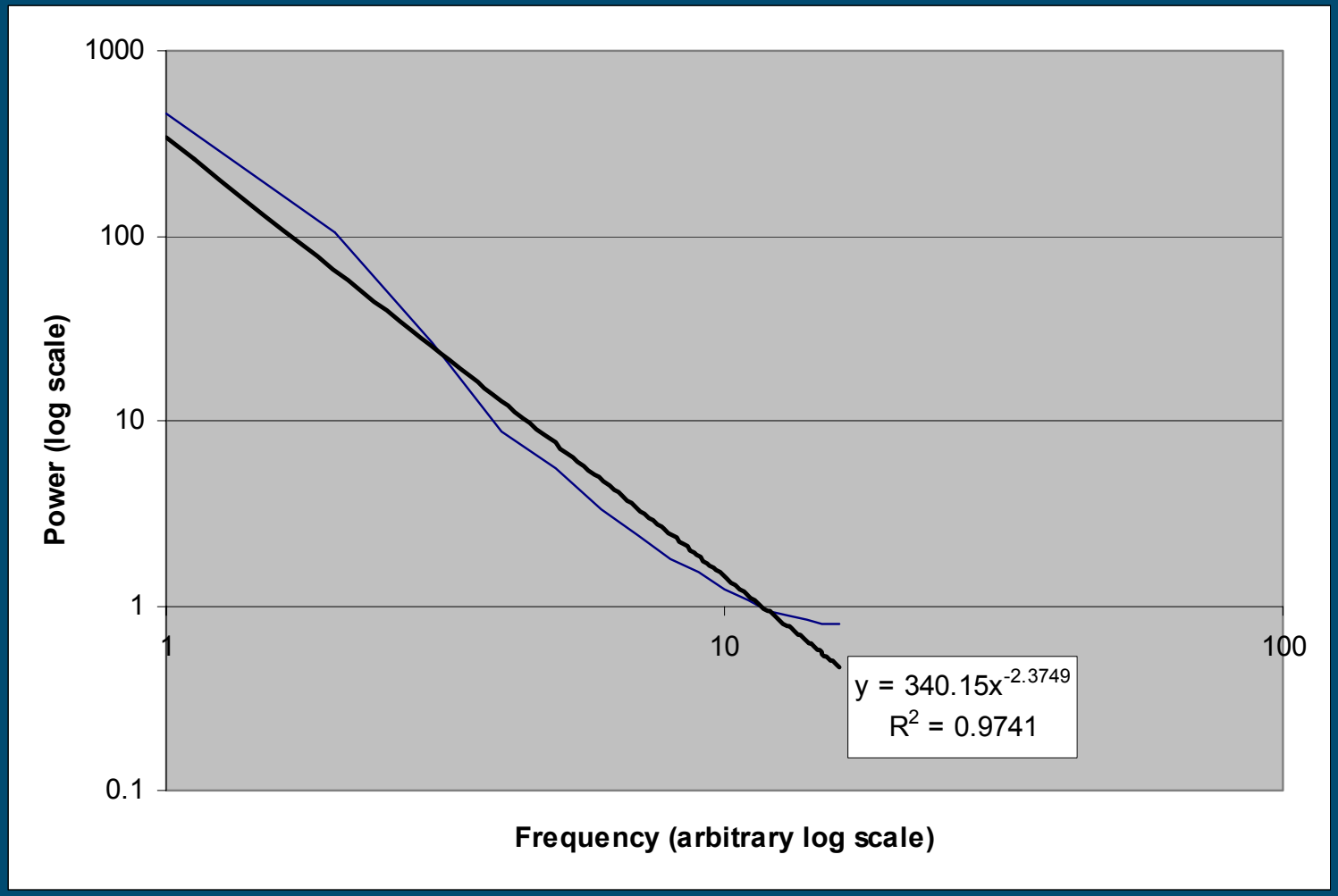
Replication results - EWF scenario



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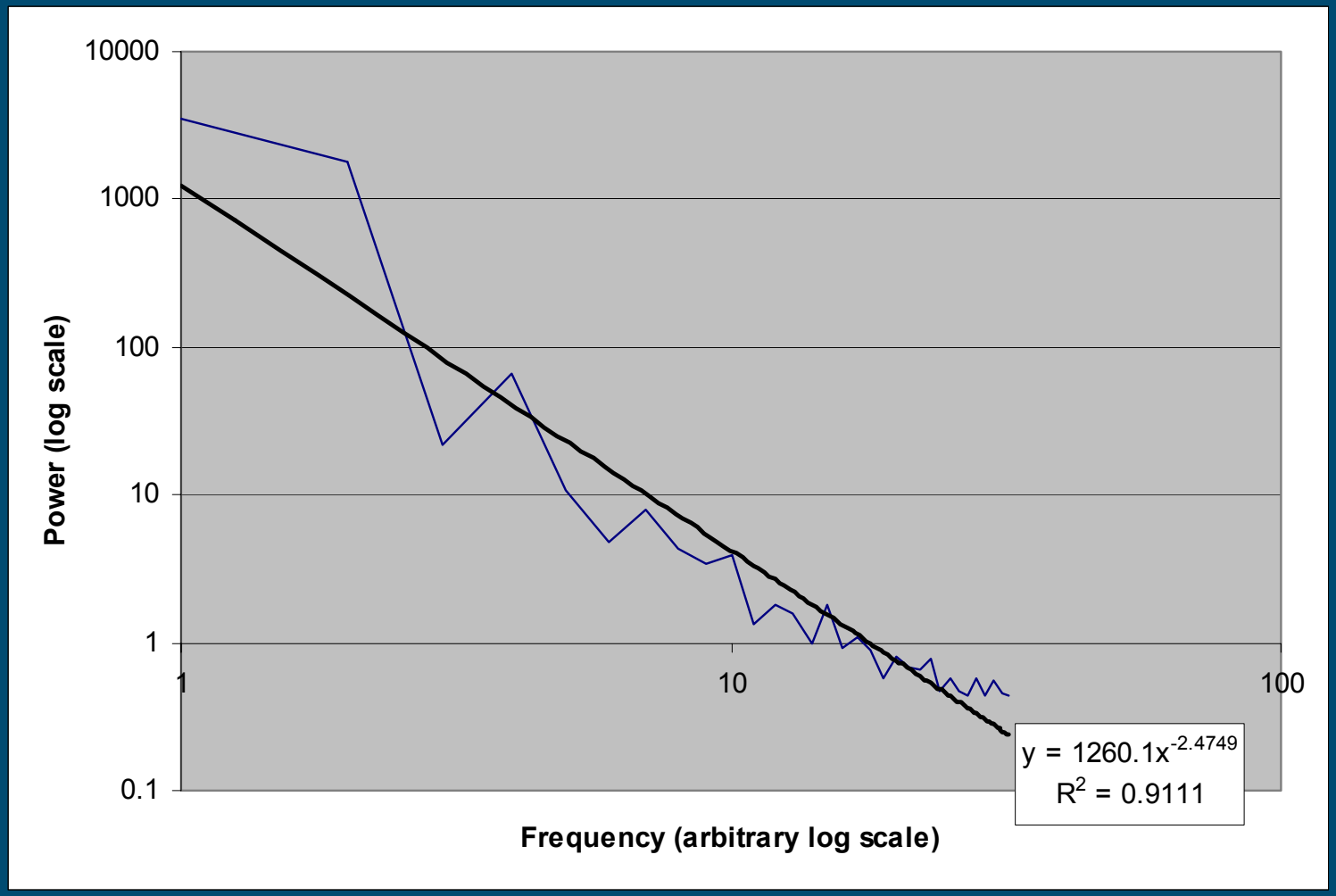
Replication results - Lanchester



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Conclusions

- Metamodel Term 1
  - Power law not disproved
- Metamodel Term 2
  - Power law not disproved
  - Gradients within predicted bounds [-3, -1]
- Confidence in results
- Metamodel not disproved so far

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Way forward

- Characterise casualties' volatility over time
  - E.g. Provision of medical facilities
- Third term of metamodel
  - Self-organised clustering of agents
- Joint development of theory and experimentation
  - Relationship between local collaboration and emergent force behaviour

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Can *emergent behaviour* in MANA be represented by a *metamodel*?

We believe, Yes

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Any questions?

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