When Physics met Politics: Physics of Politics? Politics of Physics?

當物理遇見政治：政治物理學？物理政治學？

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物理學門(Branches of Physics)：

- 凝態物理 Condensed Matter Physics
- 原子分子物理 Atomic and Molecular Physics
- 粒子物理 Particle Physics
- 天文物理 Astrophysics
- 核物理 Nuclear Physics
- 生物物理 Biophysics
- 統計物理 Statistical Physics
- ……

物理學的跨領域研究課題 (Interdisciplinary Research Topics):

- 生物科技 (Biotechnology)
- 奈米科技 (Nanotechnology)
- 資訊科技 (Information Technology)
- 社會經濟 (Social Economics)
- ……

物理研究方法運用在人文社會課題--Econophysics

- 股票市場 Stock markets
- 外匯市場 Foreign Exchange Markets
- 個人所得 Personal Income
- 社會財富分佈 Wealth Distribution
- 社會網絡 Social Networks
- ……

Pareto Law (1896)

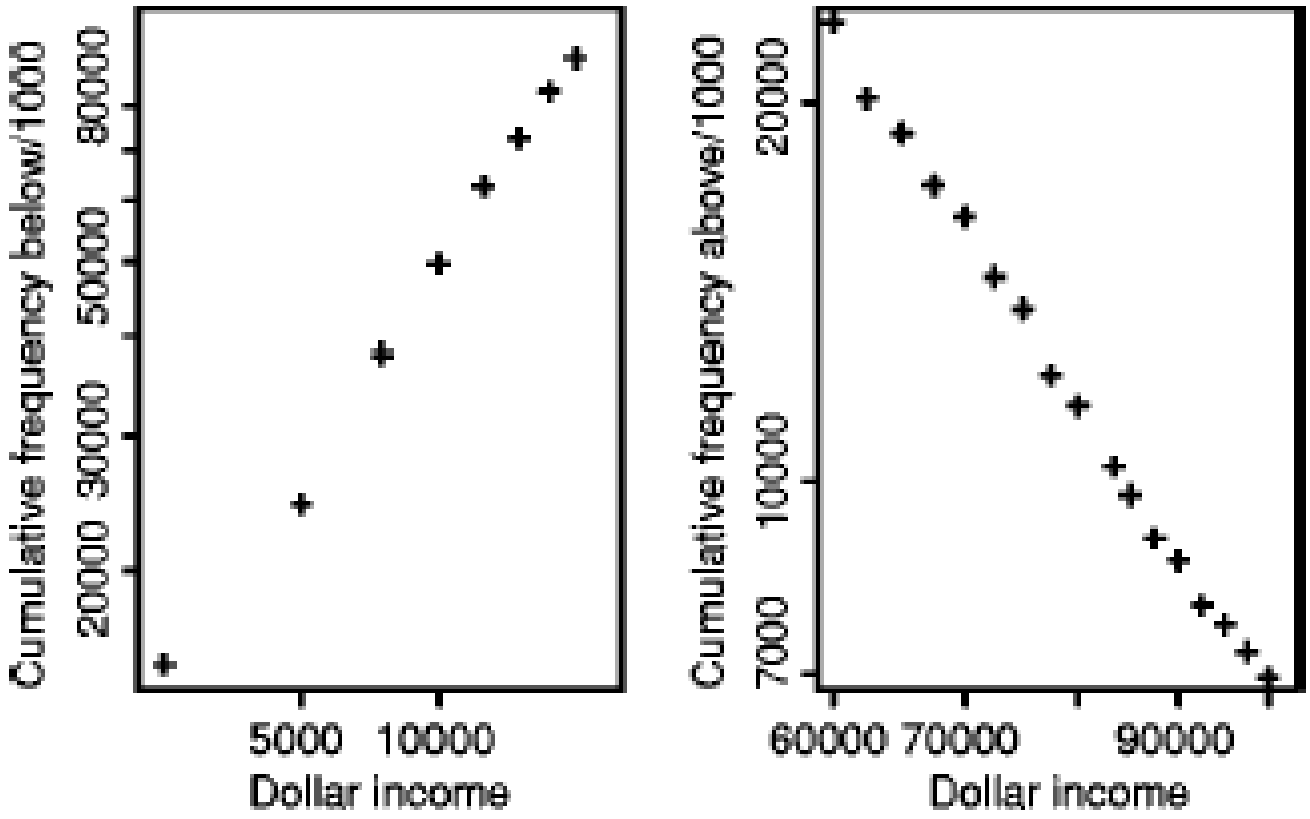
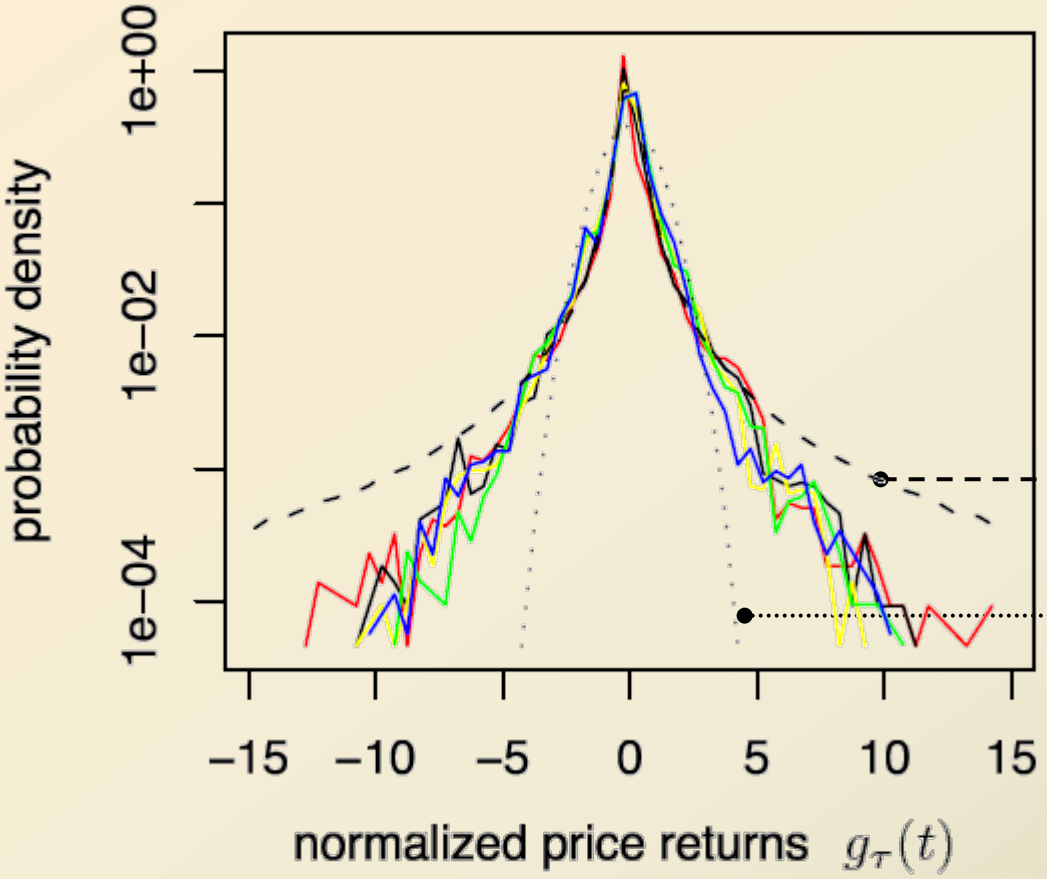
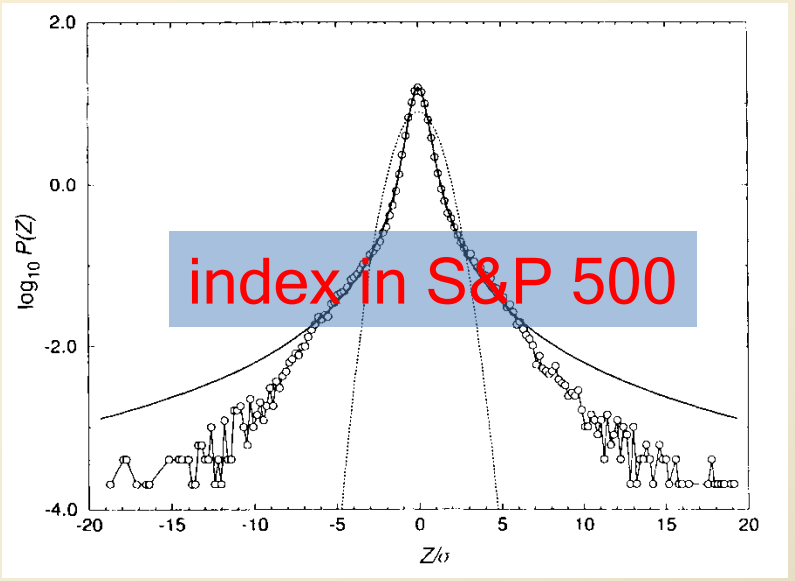
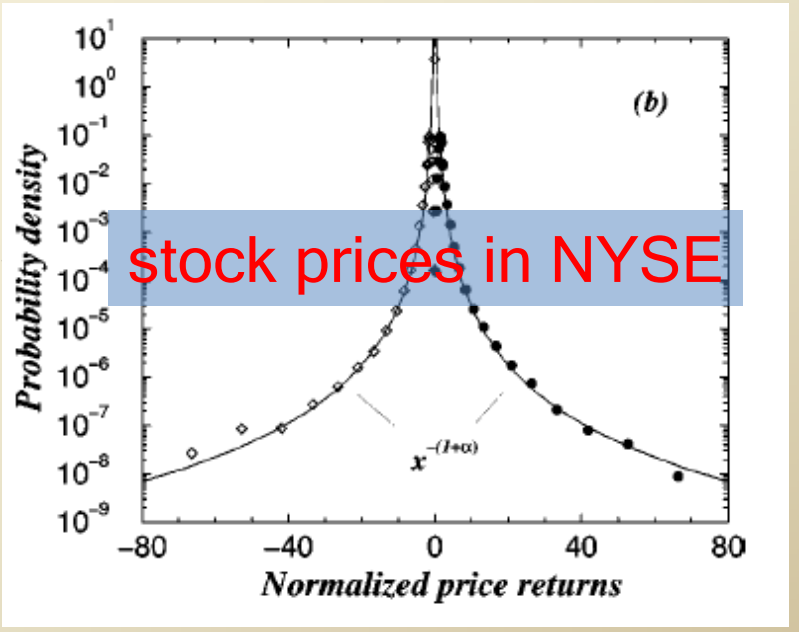


FIG. 2. Distribution of the total money income of 216×10^6 people in USA in 2000. The left and right panels show (on logarithmic axes) the cumulative frequency distributions (binned) in the lower and upper tails, respectively, suggesting power laws (unbinned income data are not available).

Price Fluctuation







物理研究方法運用在人文社會課題—

範例：政治學

(1) 選區劃分問題(Political Districting Problem)
(2) 建立一個網上政治期貨交易市場研究社會行為(Prediction Market)
(3) 得票分布(Distribution of votes)

方法 ：

統計物理 (Statistical Physics)

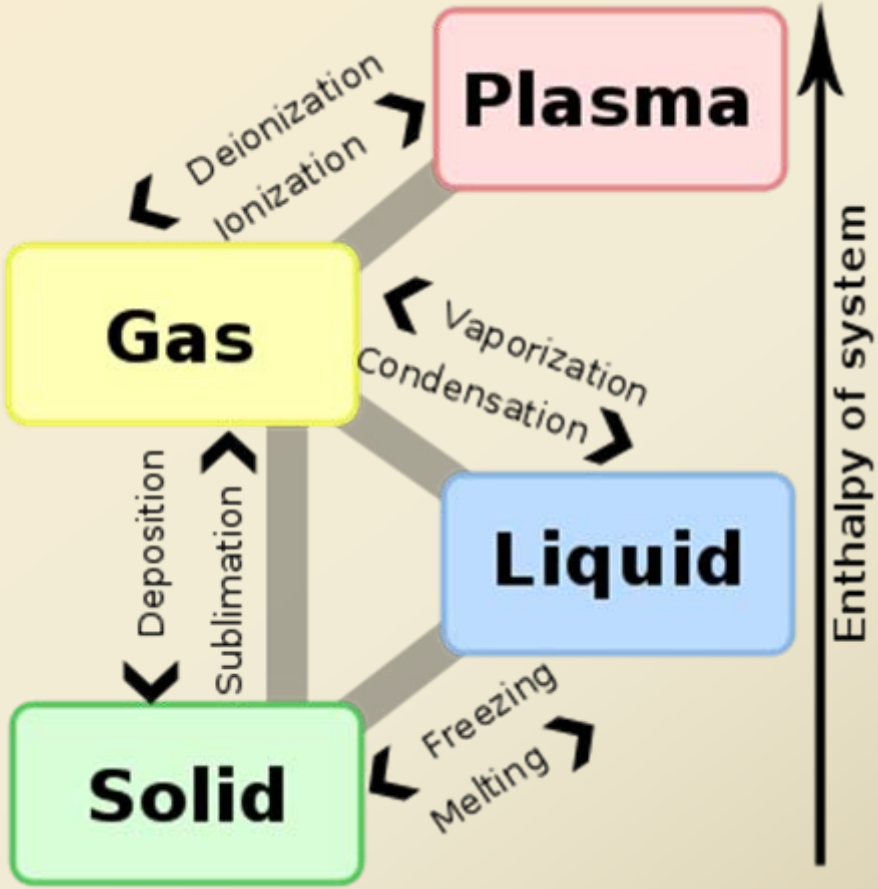
統計物理學是研究大量粒子集合的宏觀運動規律的一門科學。所用到的方法包括統計及概率等數學工具。簡單來說，**統計物理學**也是研究複雜系統的一門學科。

What is a Complex System (複雜系統)?

複雜系統是一個由多個簡單單元所組成的結構。一般來講, 複雜系統最有趣的地方在於所組成的單元經由非線性交互作用，會產生集体的行為。這些集体行為可在空間或時間中表現為圖形化、新層次之結構。這類系統往往受外界影響，而在熱力、噪音的作用下運作。要瞭解這些系統的行為，我們需要運用熱力學和統計力學的概念和方法。

相變(Phase Transition)

相變是指物質從一種相（態）變成另一種相，最常見的是冰變成水和水變成蒸氣。



蝴蝶效應(Butterfly Effect)

蝴蝶效應
(Butterfly Effect)

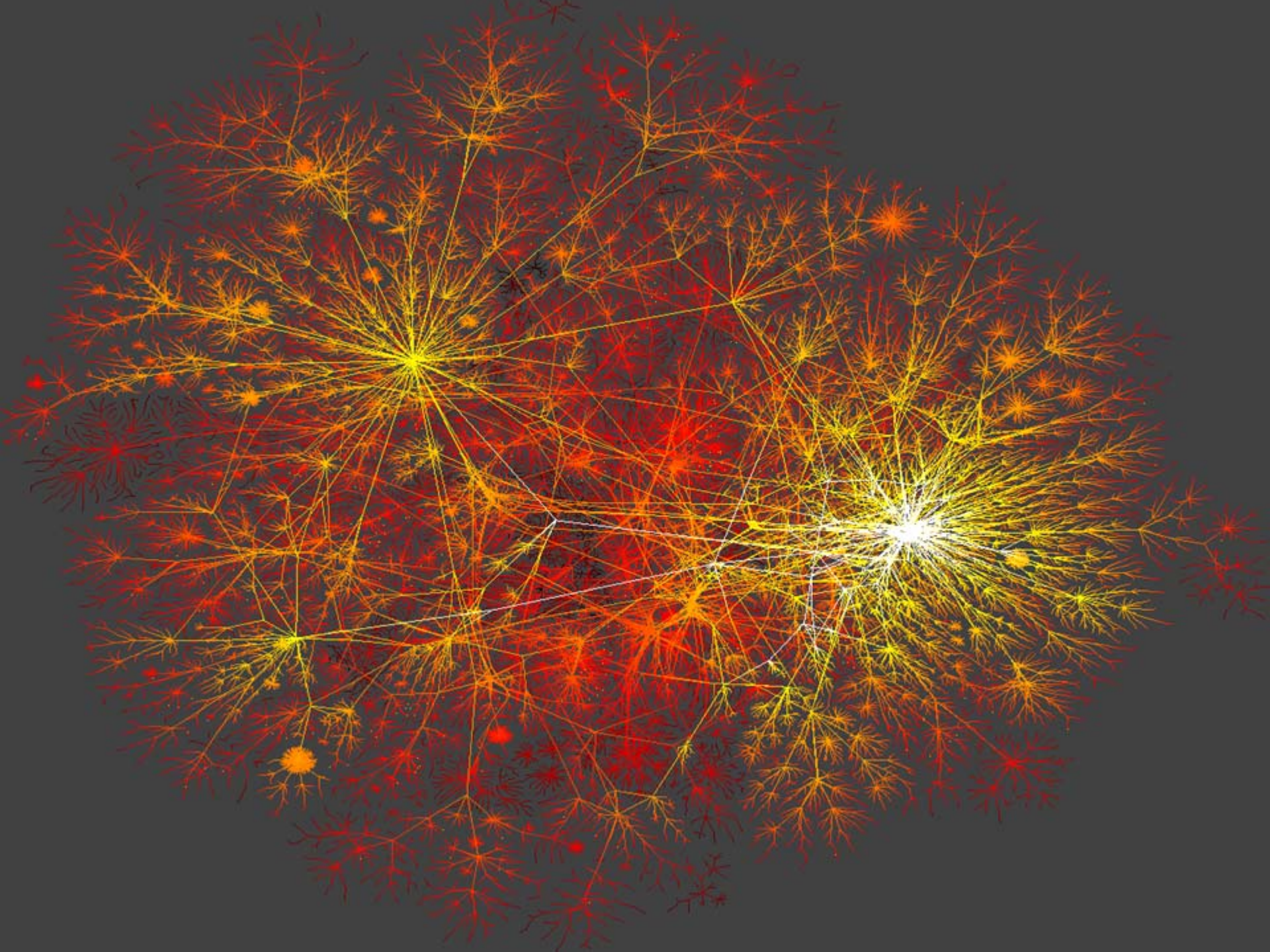
一隻蝴蝶在巴西輕拍翅膀，會使更多蝴蝶跟著一起輕拍翅膀，其所產生的影響可以導致一個月後在美國德州發生一場龍捲風。

蝴蝶效應（**Butterfly Effect**）是指在一個動力系統中，初始條件下微小的變化能帶動整個系統的長期的巨大的連鎖反應。

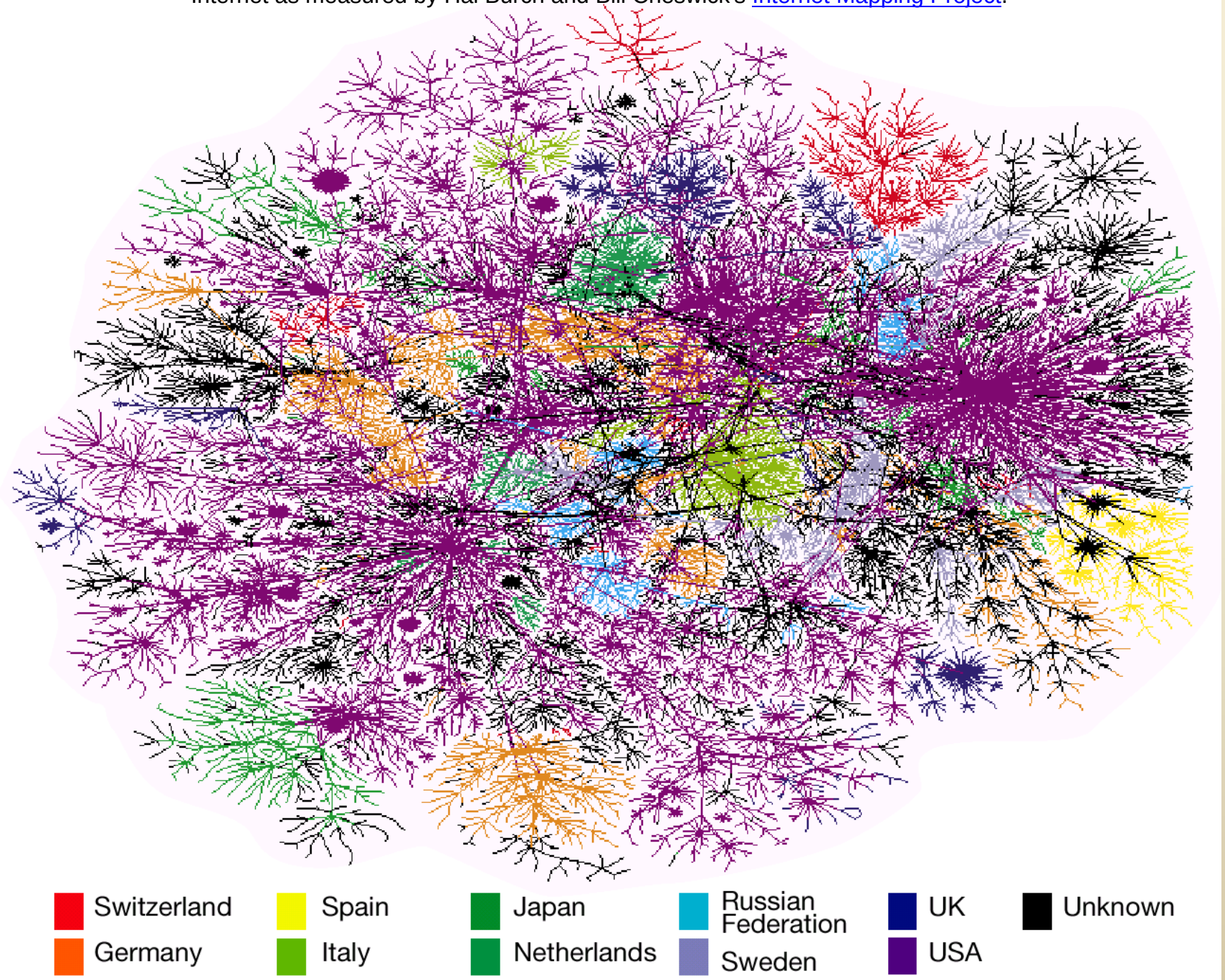
Complex Networks (複雜網絡)

In the context of network theory, a **complex network** is a network (graph) with non-trivial topological features—features that do not occur in simple networks such as lattices or random graphs.

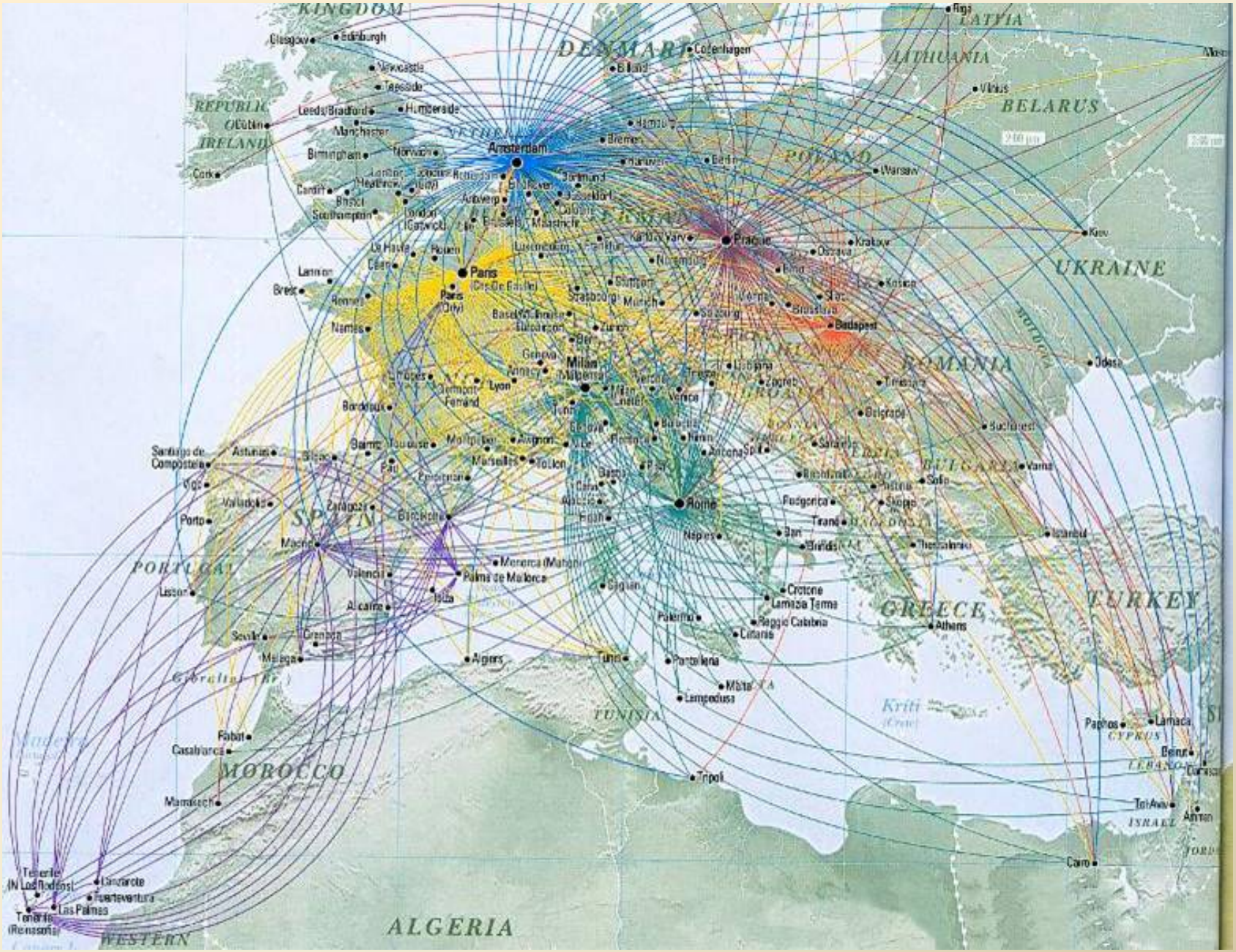
The study of complex networks is a young and active area of scientific research inspired largely by the empirical study of real-world networks such as computer networks and social networks.



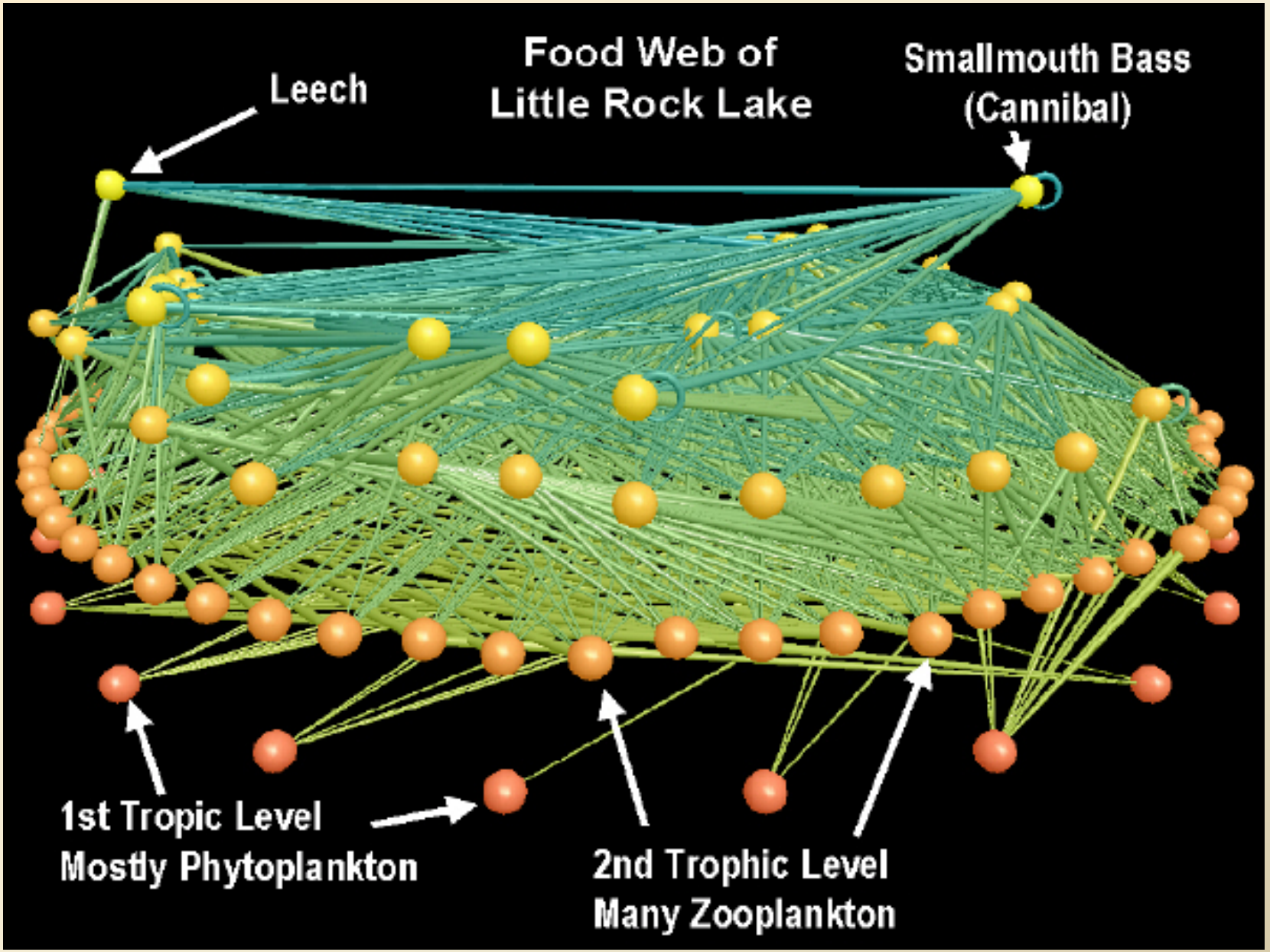
Internet as measured by Hal Burch and Bill Cheswick's Internet Mapping Project.



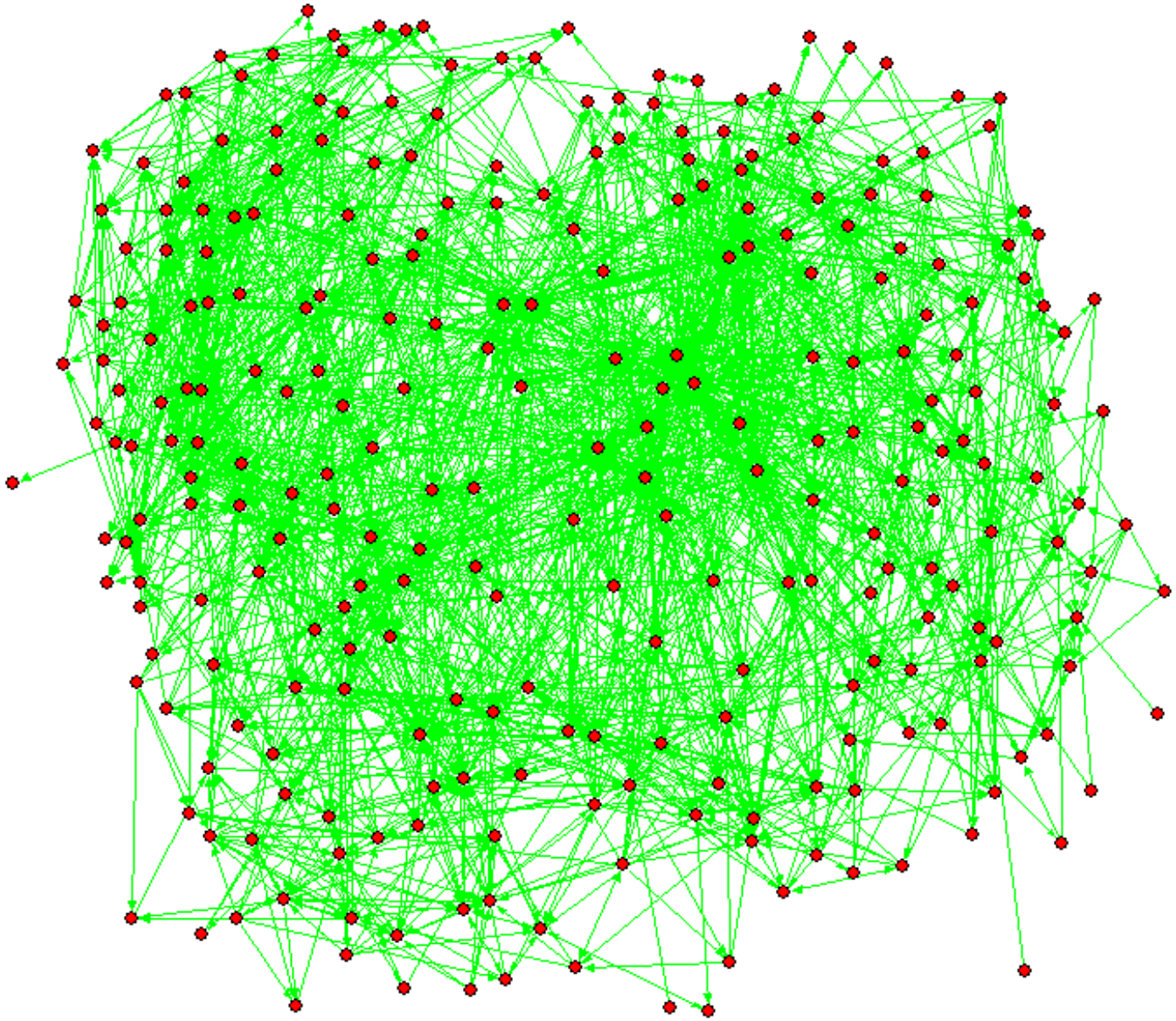
transportation networks: airlines



Freshwater food web by Neo Martinez and Richard Williams

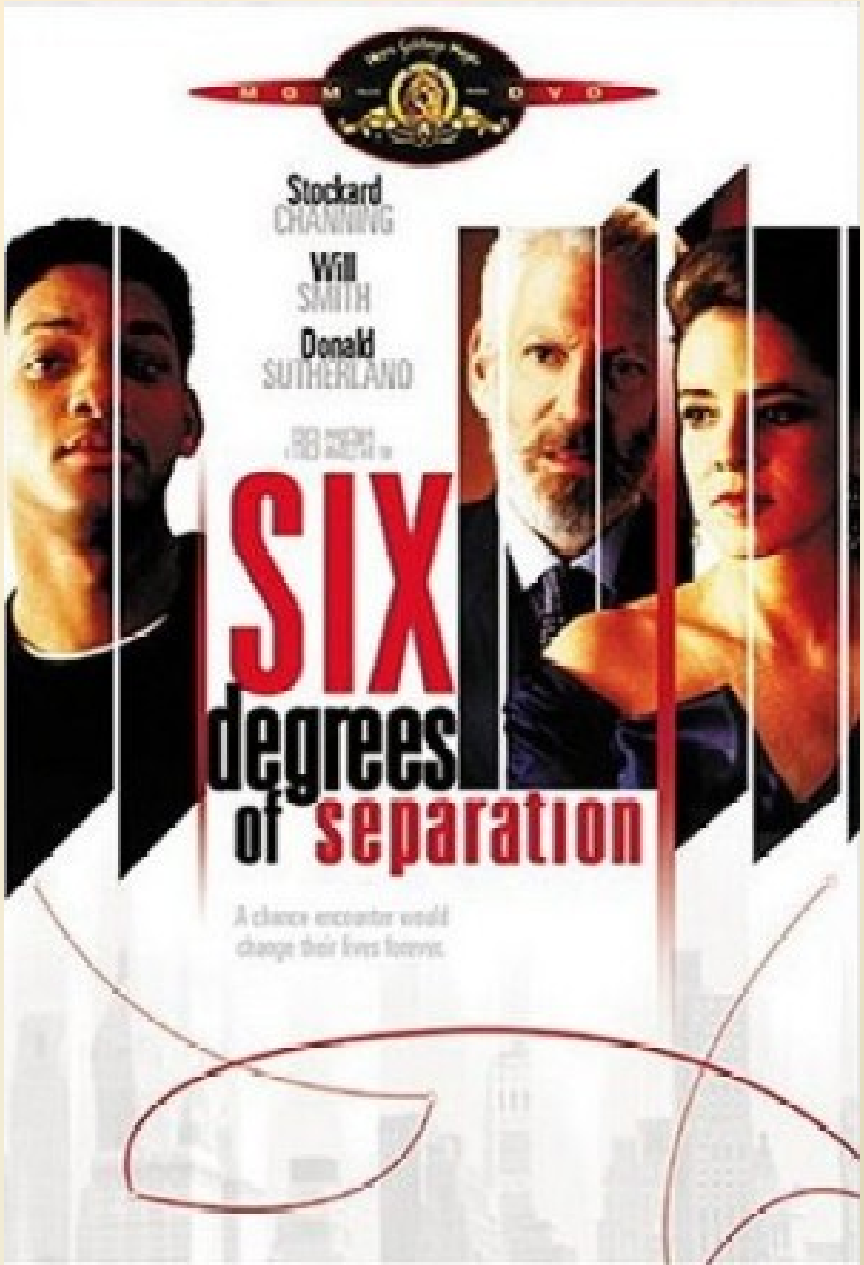


C. elegans neurons



Network of actor co-starring in movies

六度分隔 (Six Degrees of Separation)



六度分隔 (Six Degrees of Separation)

- 「不管是美國總統還是威尼斯的船夫，只要找到正確的6個人，我們就能聯繫起來」。

- 1967年哈佛大學的心理學教授 Stanley Milgram 根據這概念做過一次**連鎖信實驗**，嘗試證明平均只需六個人就可以聯繫任何兩個互不相識的美國人。

- 1998年Watts and Strogatz – Small World (小世界):假設世界上所有互不相識的人只需要很少中間人就能建立起聯繫。

Political Districting Problem

選區劃分問題

Motivation –

The 2008 Legislature Election in Taiwan adopted a new districting system. Each voter can only vote for the legislator of his/her district.

Example: Taipei consists of 8 districts and elects 8 legislators, each from one district.

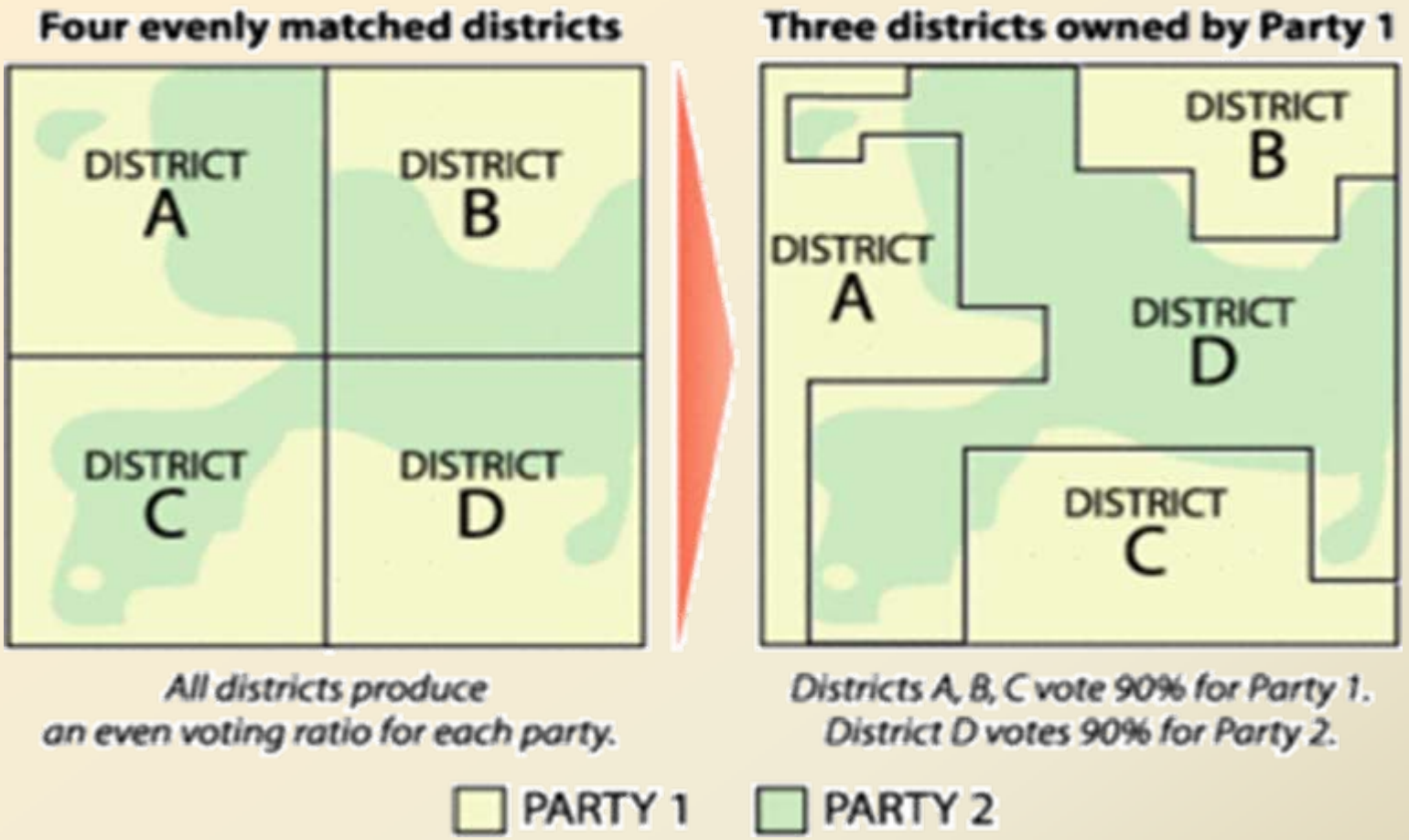
Gerrymander — 傑利蠑螈

Definition:

Rearrangement of voting districts so as to favor the party in power.

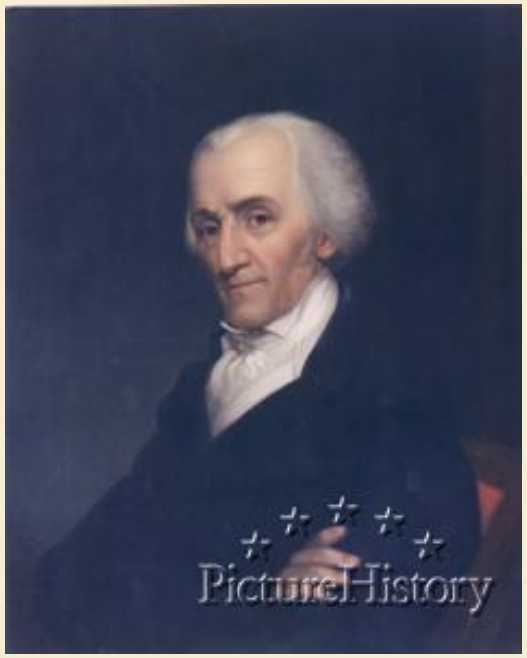
Objective:

To create as many districts as possible in areas of known support and to concentrate the opposition's strength into as few districts as possible (***packing***), or to diffuse minority strength across many districts (***dilution***).



Redrawing electoral districts in this example creates a guaranteed 3-to-1 advantage in representation for Party 1 as Party 2's voters are *packed* into District D.

Elbridge Gerry + Salamander



= GERRYMANDER

Elbridge Gerry

Birth: Jul. 17, 1744 Death: Nov. 23, 1814

One of the few politicians whose name created a word in the English language: ***Gerrymander***. Born at Marblehead, Massachusetts in 1744, he entered Harvard University at age 14, graduating with a Master's Degree in 1765 at age 20.

…….

In 1812, Governor Elbridge Gerry attempted to have a bill passed in the Massachusetts legislature that would have divided the state into special districts for election purposes; districts that would have ensured that Gerry's anti-federalist friends would be elected and his opponents would be defeated. As the shape of one of the new districts had the appearance of a mythical animal, which others claimed looked something like a salamander, the news media named it a gerrymander.

Political Districting Problem: （選區劃分問題）

--*n* units are grouped into *k* zones, subject to constraints on the topology of the zones, etc.

Mathematically, it belongs to what is known as the Districting (or zone design) Problem such that some cost function is optimized, and has been shown to be NP-Complete.

Additional Constraint: Contiguity

-- every unit in a district is connected to every other unit through units that are also in the district.

To avoid Gerrymandering, one should have:

Population equality
Contiguity
Geographical compactness

Task:

To devise a method that is able to produce solutions which satisfy these characteristics.

Example: USA

Each state's legislative body is responsible for partitioning its state into districts (***district plan***) equal to its apportionment.

Traditional Districting Principles for the plan

-- contiguity

-- equal population

-- pleasing shape

-- should not depart from the previous plan dramatically

-- …..

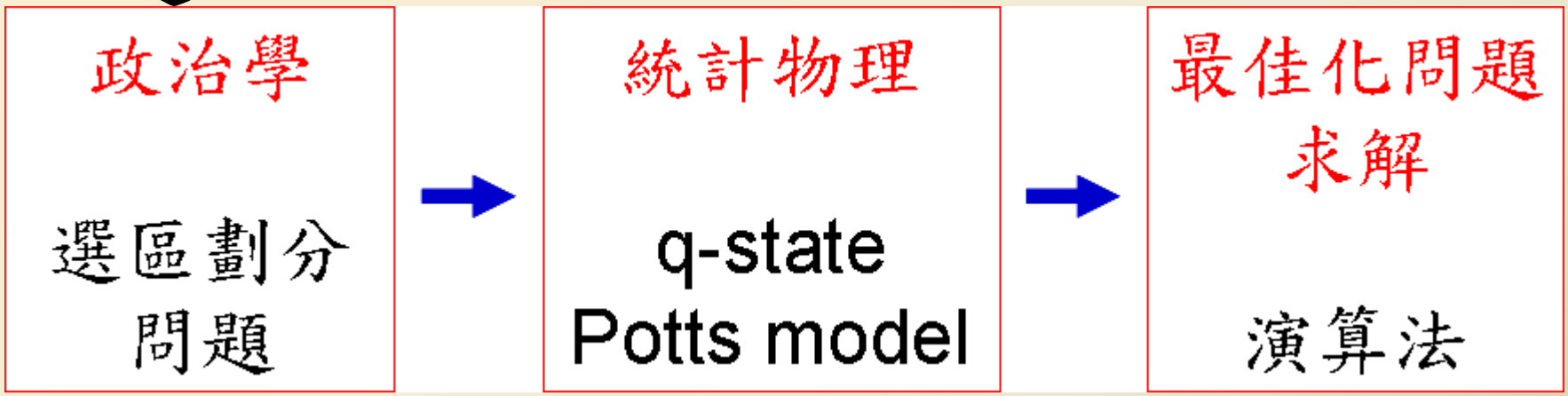
Our Approach –

To map the problem onto a statistical physics model and to find its optimal solution.

Our Choice – q-state Potts Model

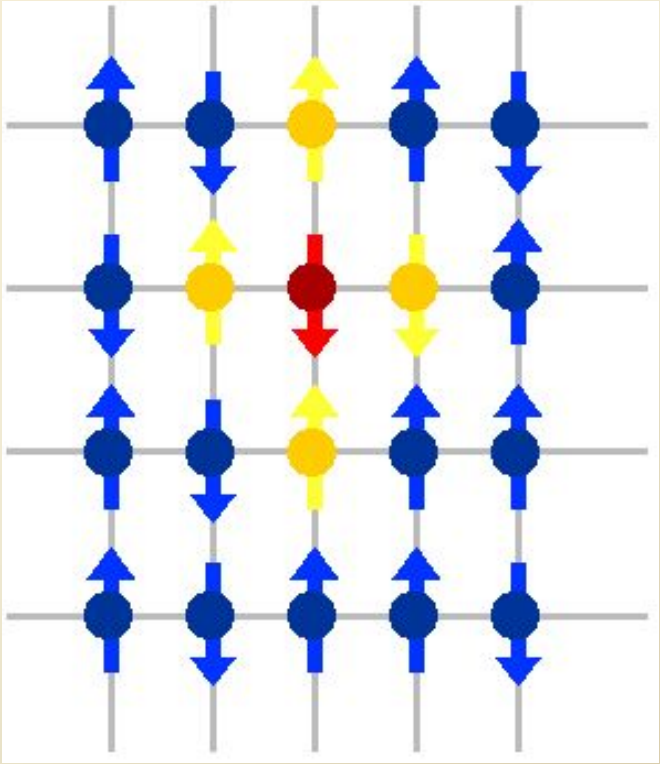
選區劃分問題

- 而整個政治上選區劃分問題，就轉化為 Potts 模型系統如何求基態解的最佳化問題。



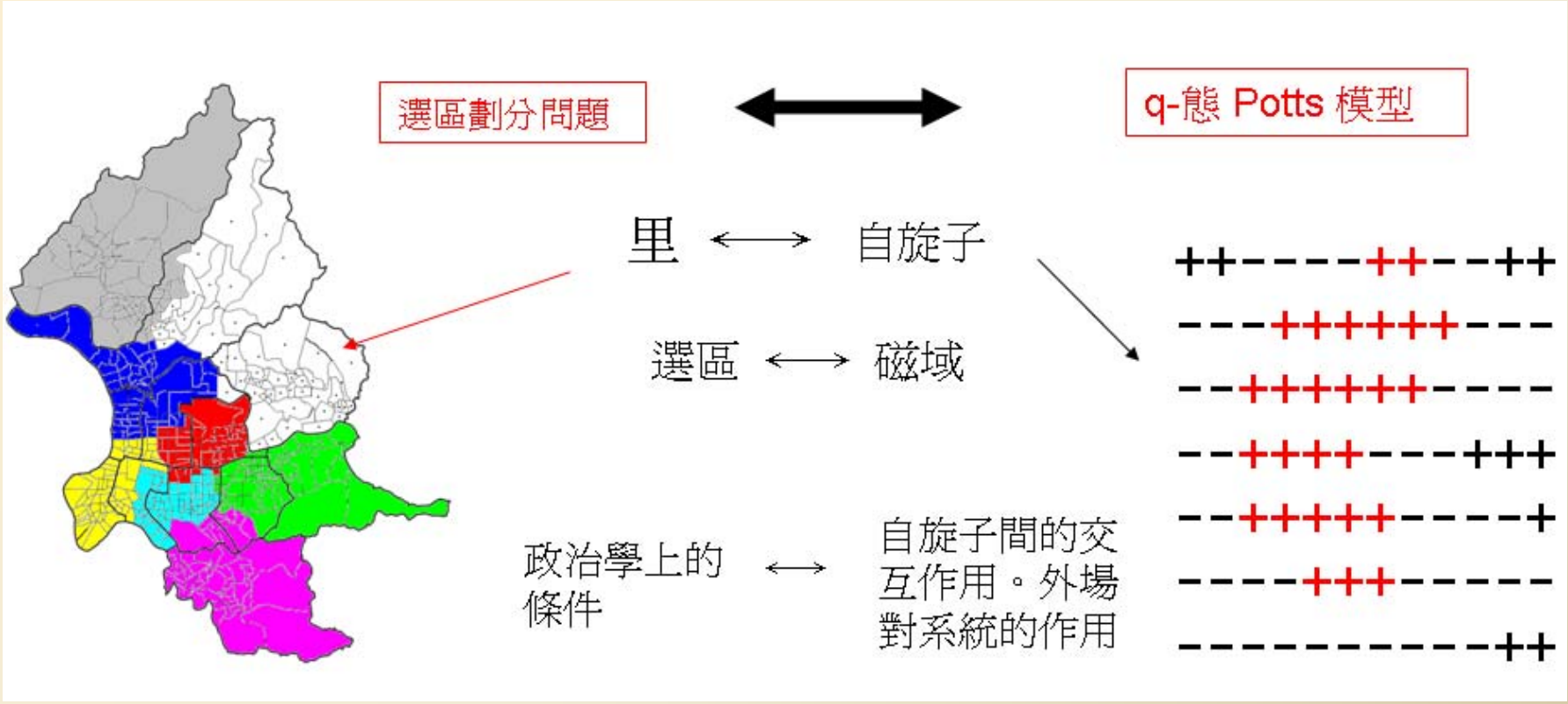
Ising Model—A Model for Magnets

The motion of electrons around a nucleus can produce a (tiny) magnetic field associated with an individual atom. In many respects, these atomic magnets are like ordinary magnets and can be thought of in terms of little magnet vectors. In most ordinary matter, these little atomic magnets are pointing in random directions. The magnetic fields from the individual atoms cancel, and there is no overall magnetic field in any (macroscopic) clump of matter. However, in some materials, such as iron, it is possible for very large numbers of the little atomic magnets to line up, giving a non-zero total magnetic field at "human perceptible" distances.



選區劃分問題

- 我們將這個政治學上的問題映射到一個統計物理中的 q-state Potts 模型系統的問題。



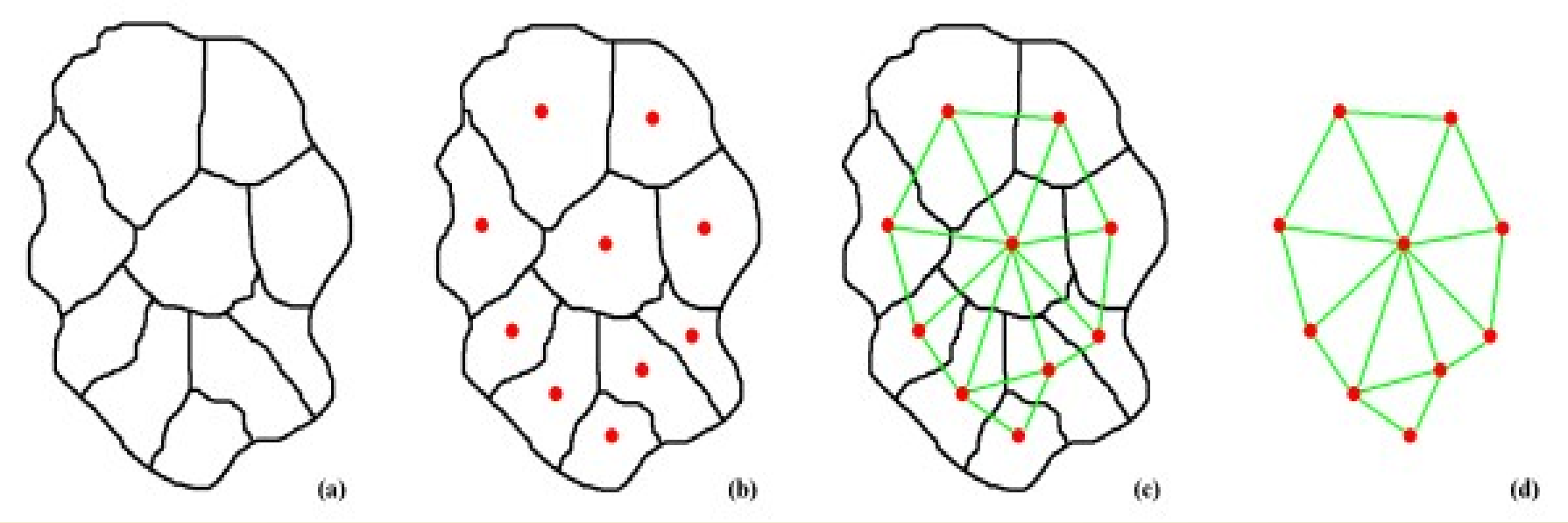


Fig. 2. (a) A district of 10 precincts in our model; (b) each red dot represents one precinct; (c) a network of precincts connected by green arcs; (d) the network extracted from (c).

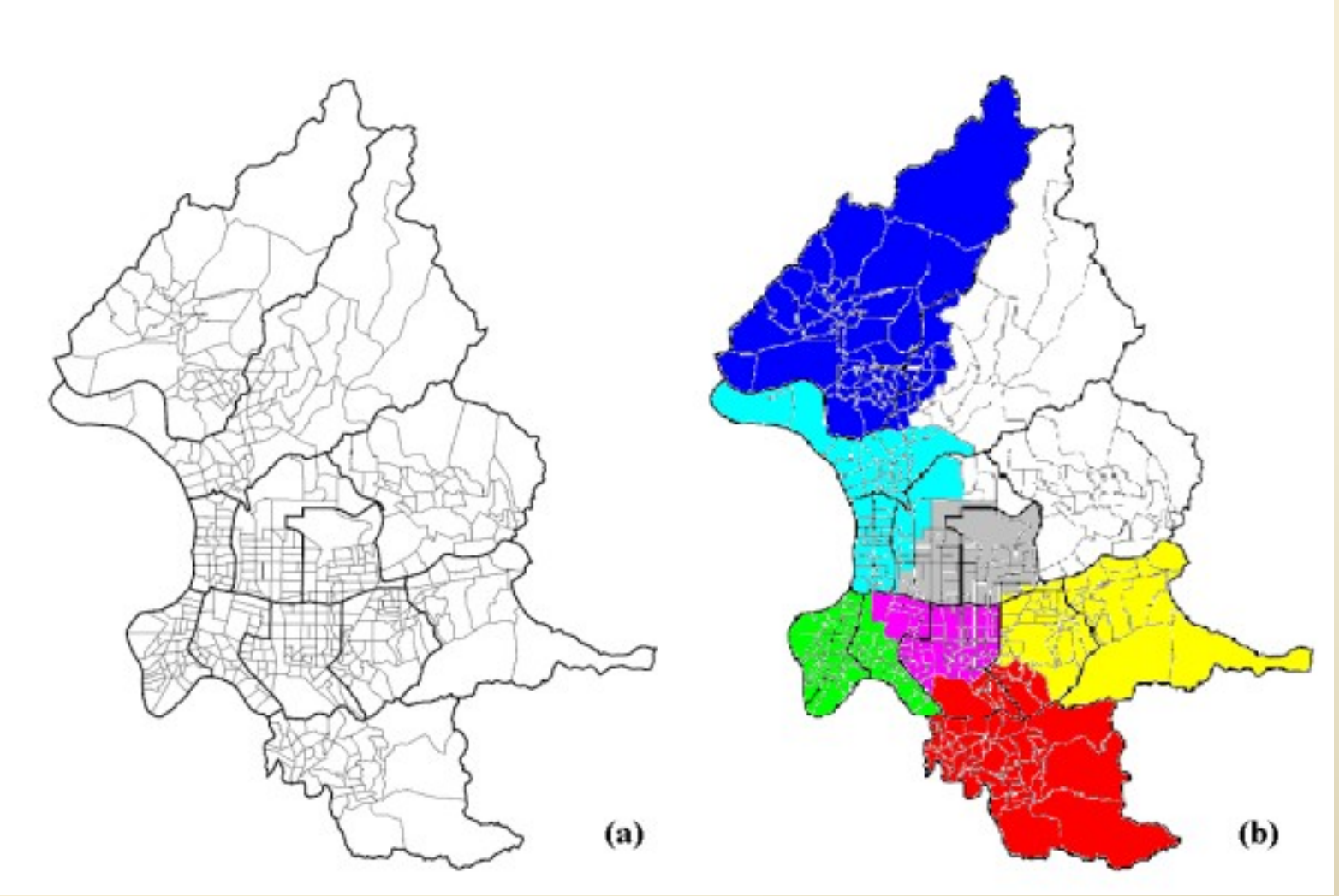


Fig. 8. (a) A map of the Taipei city and its 449 precincts; (b) an illustration of the voter districting in lowest energy state from our simulation with λ_P and λ_D equal to 50 and 1 respectively. The 8 voter districts are drawn in different colors.

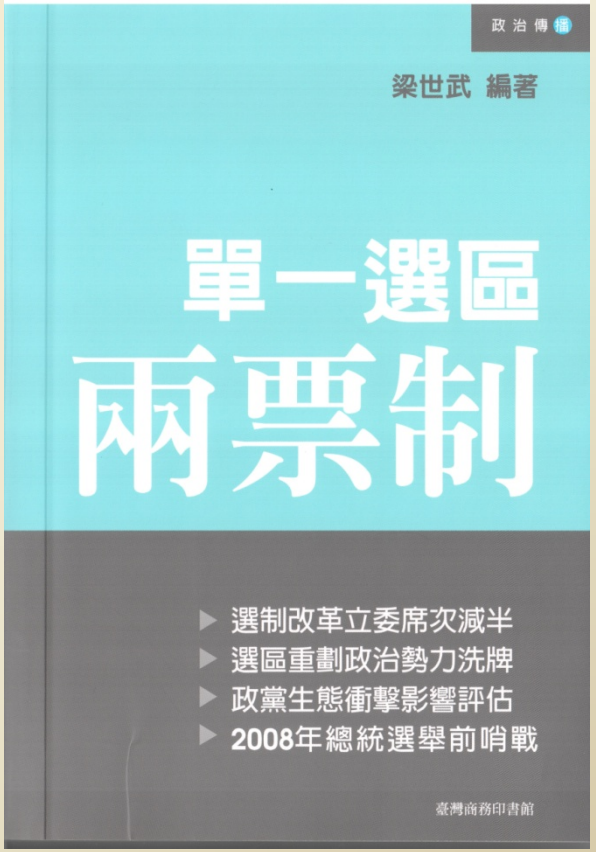
Summary on

Political Districting Problem (2006)

- A statistical approach to Political Districting Problem is given
- Additional constraints can be introduced as interaction among sites and/or external fields
- Collaboration with other organizations, e.g. Central Election Commission (CEC), to solve real life problem

Summary on Political Districting Problem (2008)

- 跨領域整合的挑戰
  - ●研究人員的合作
  - ●跨領域出版
- 計量政治學的新方向 (Quantitative Political Science)
  - ●新的想法
  - ●如何實踐
- 更多的應用
  - ●其他的區域劃分與樓層規劃



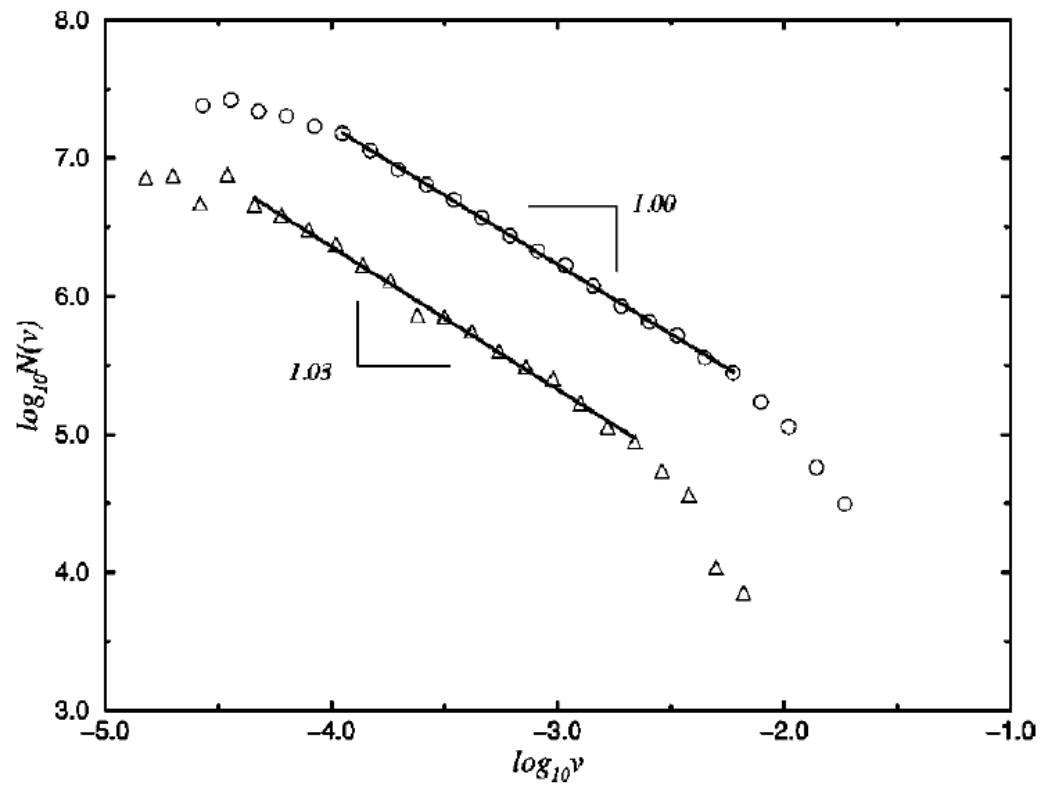
Distribution of Votes

(得票分佈問題)

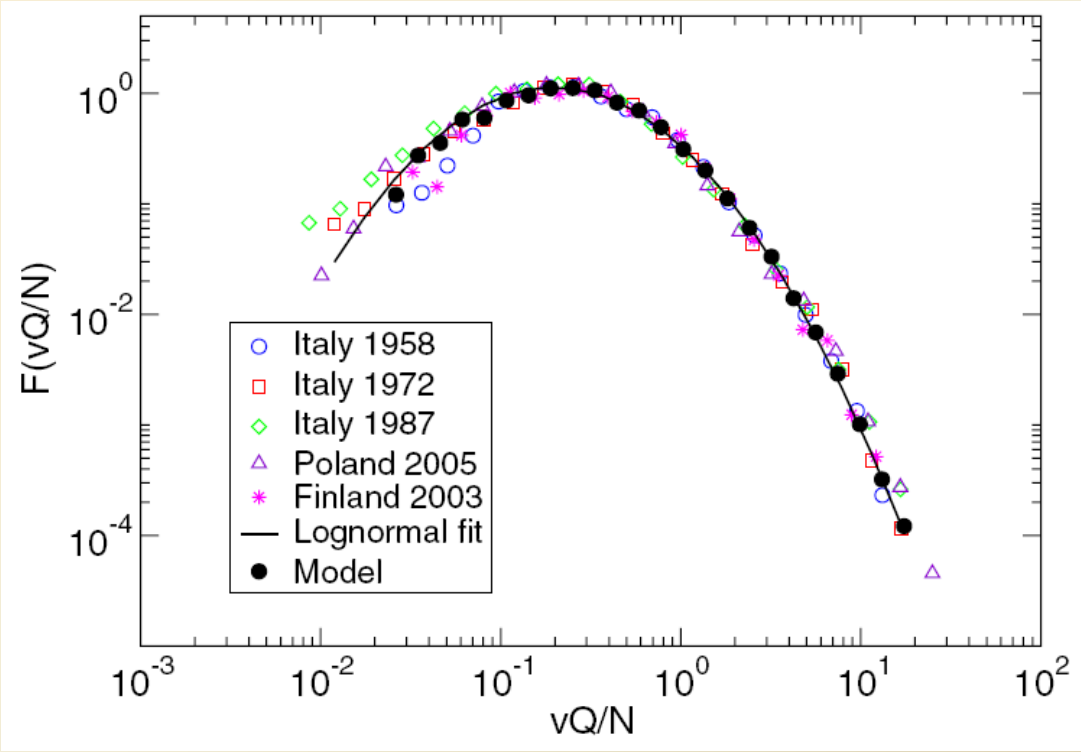
Distribution of Votes (得票分佈問題)

- 在選舉中，候選人得到全部選票的一部份 *v*，如果對此做統計分析，將會發現得到 *v* 選票的候選人數目 *n(v)* ，往往符合某些特殊的統計分佈。
- 文獻中的結果可分為兩大類，一是冪次率(*power law*)下降分佈。另一種是對數常態(*log-normal*)分佈。

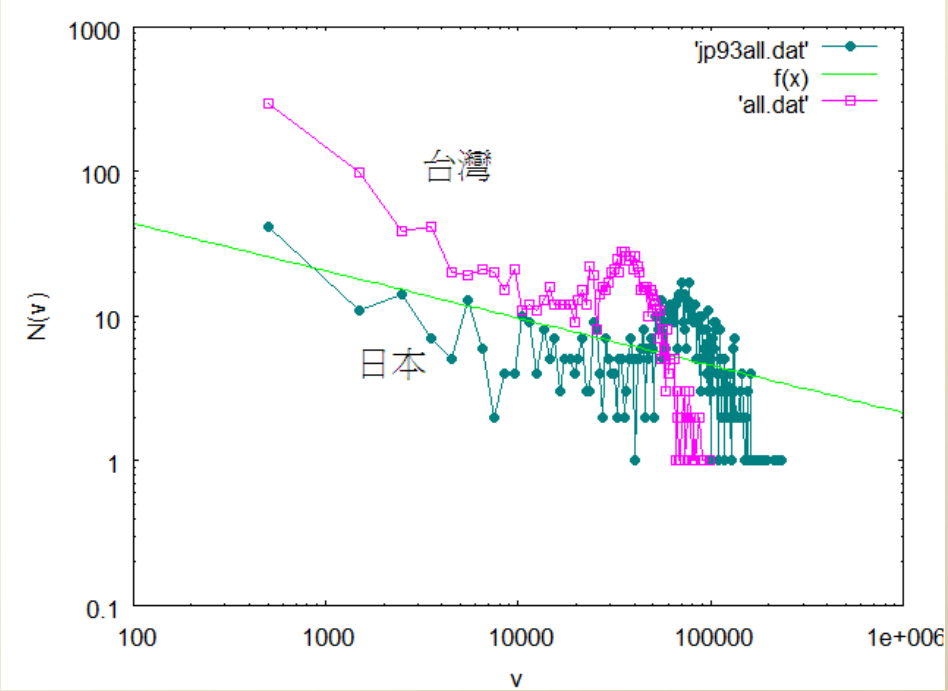
- 冪次率(*power law*)下降分佈，*n(v)* 約正比於 *1/v*。這種結果出現在較早的巴西等國的國會選舉研究中。



- 在義大利等國的國會選舉研究中出現的現象，這些選舉顯示 v 與 n(v) 成對數常態(*log-normal*)分佈。
- 兩種結果差異的解釋？

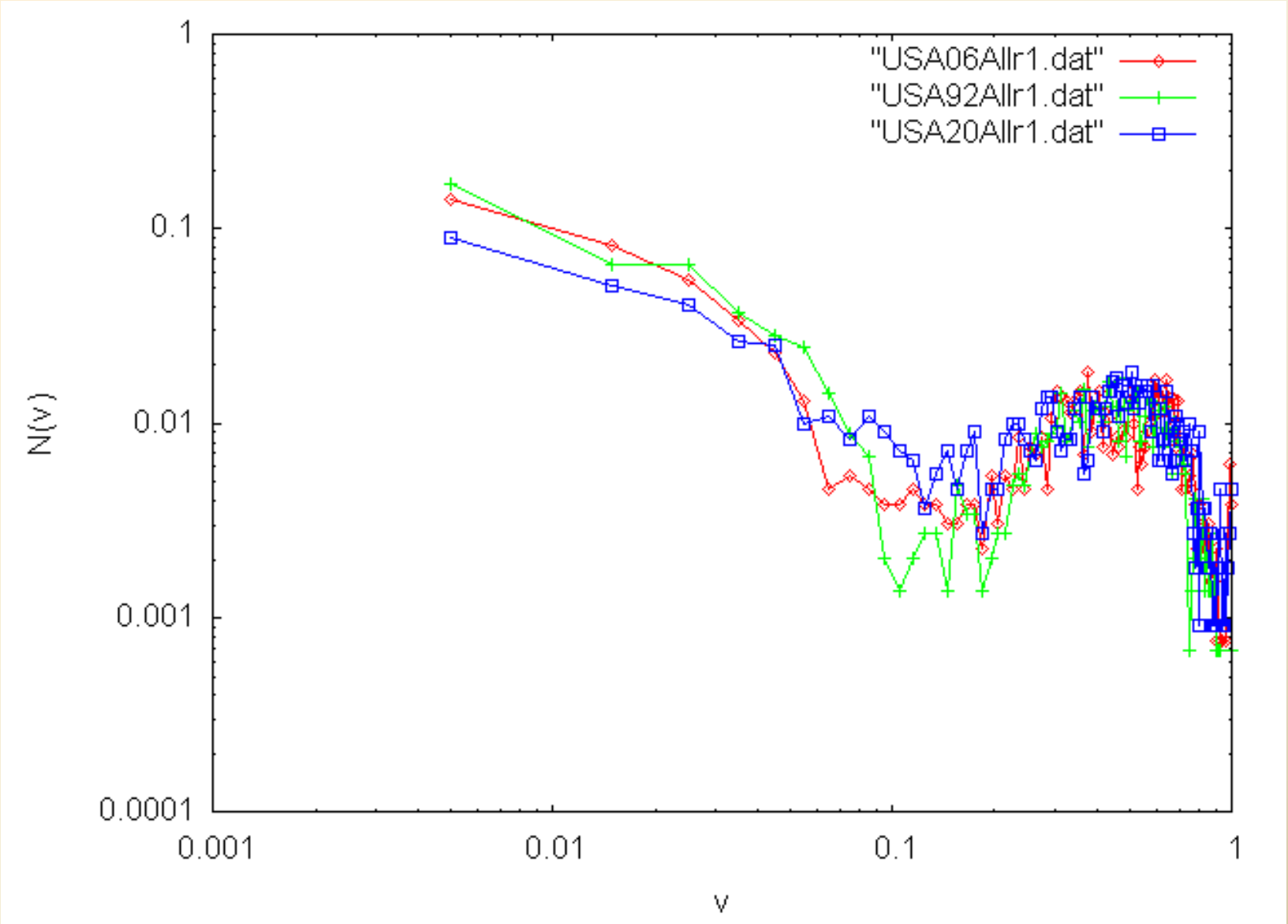


- 我們對台灣立法委員與日本眾議員選舉做了一些研究。
- 由於特殊選制的關係，候選人得票結果的分佈，出現了上述文獻中的兩類分佈的組合現象。

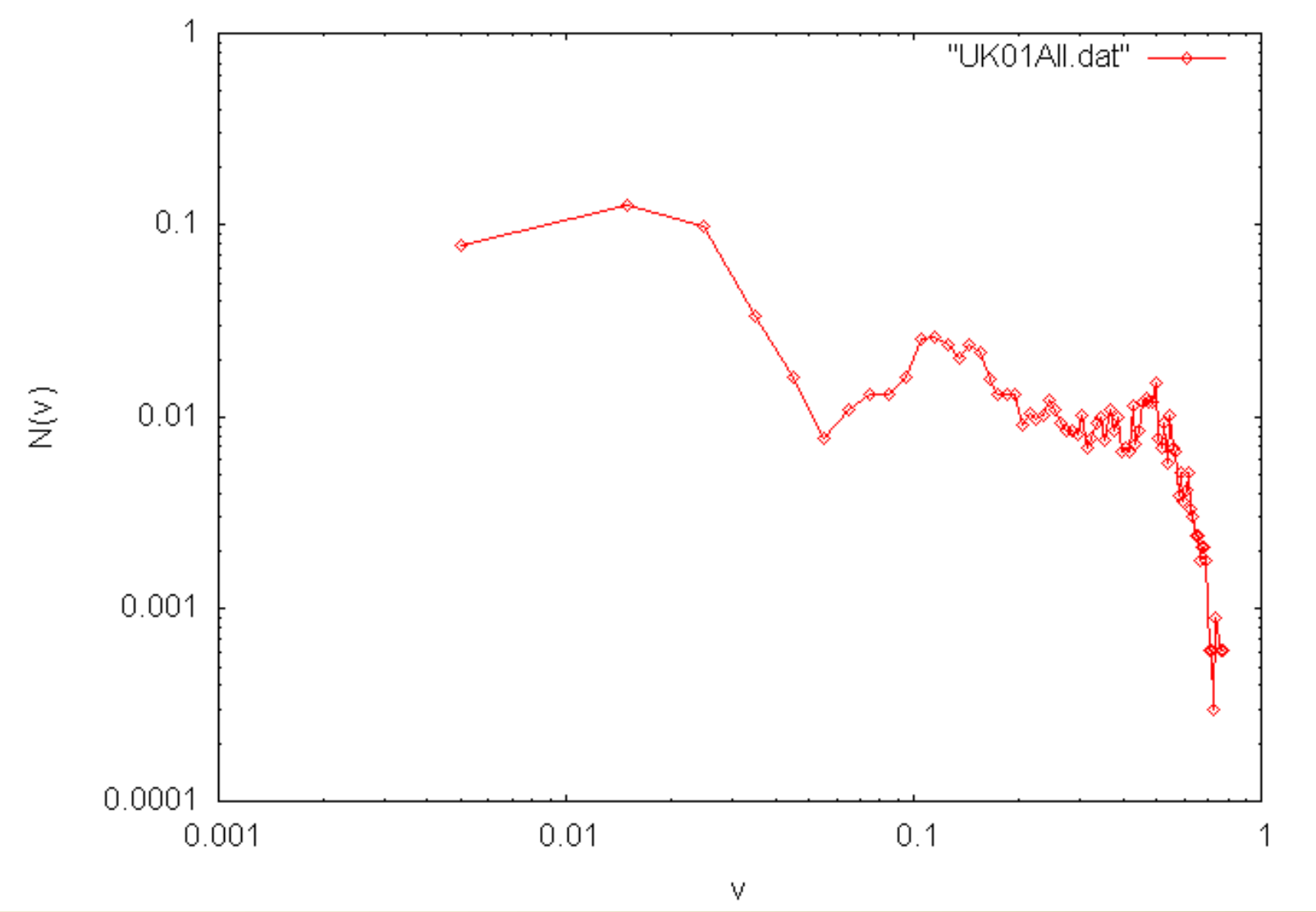


台灣立法委員選舉與1993 年日本眾議員選舉，參選人得票分佈

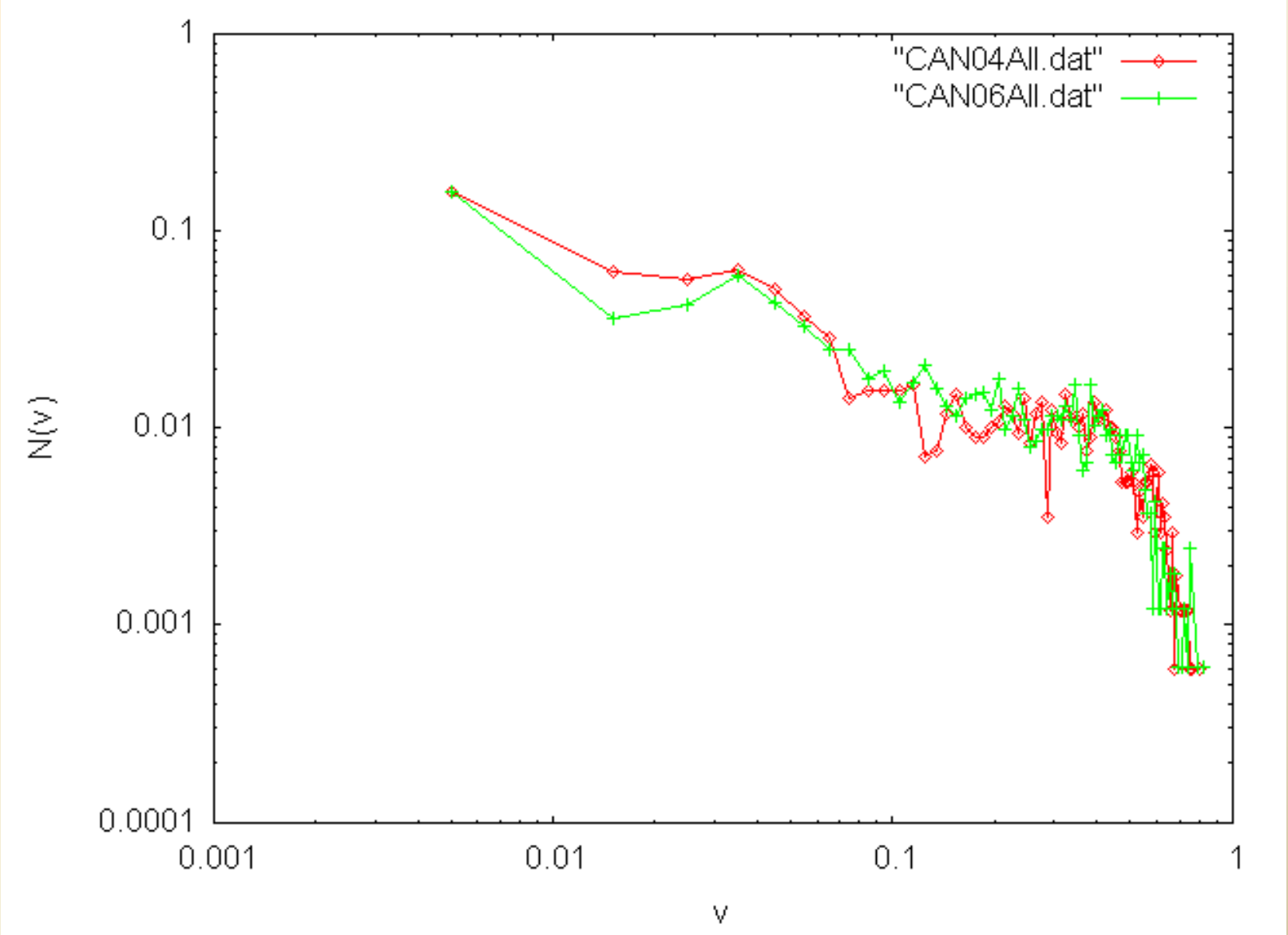
USA House of Representatives



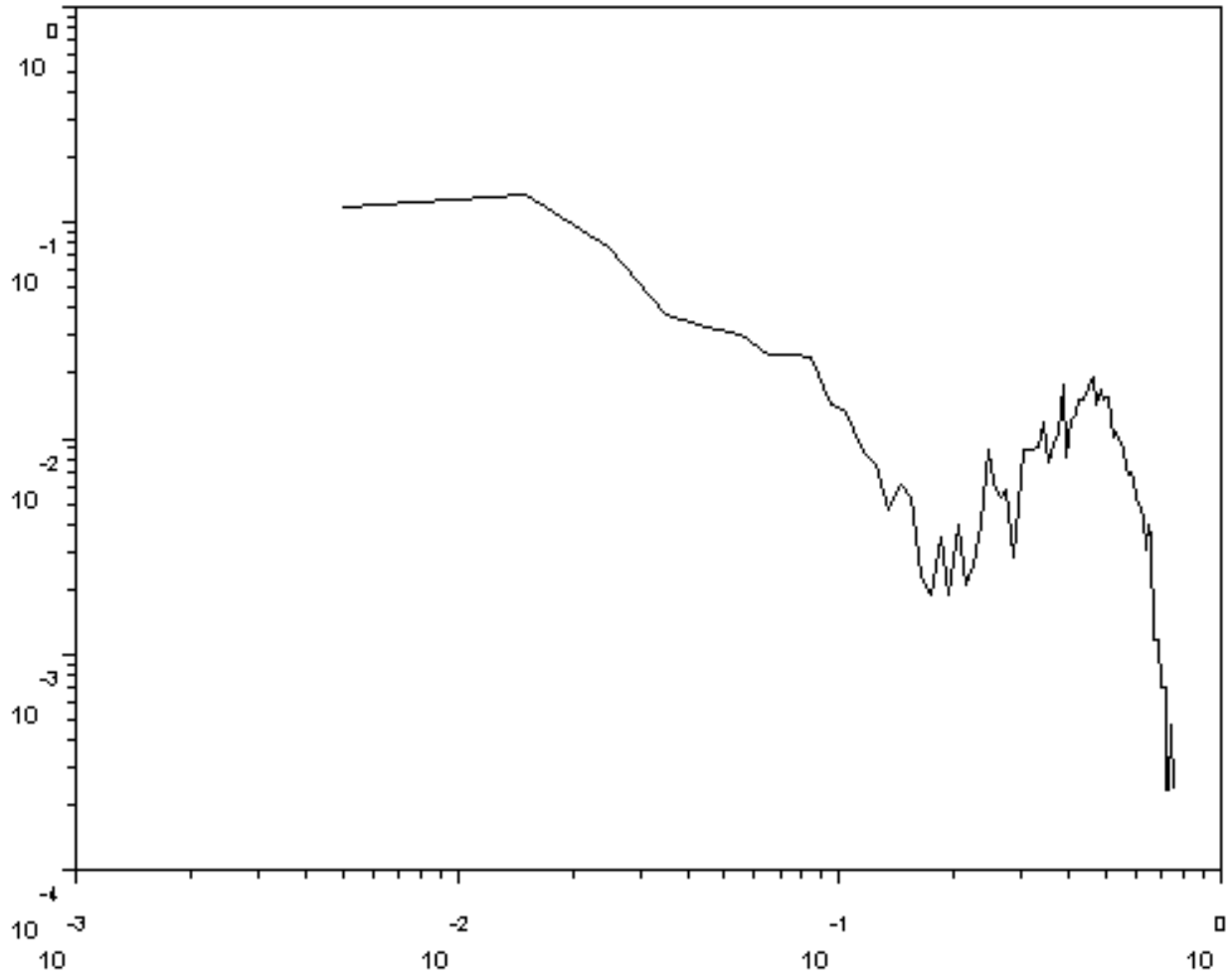
UK 2001



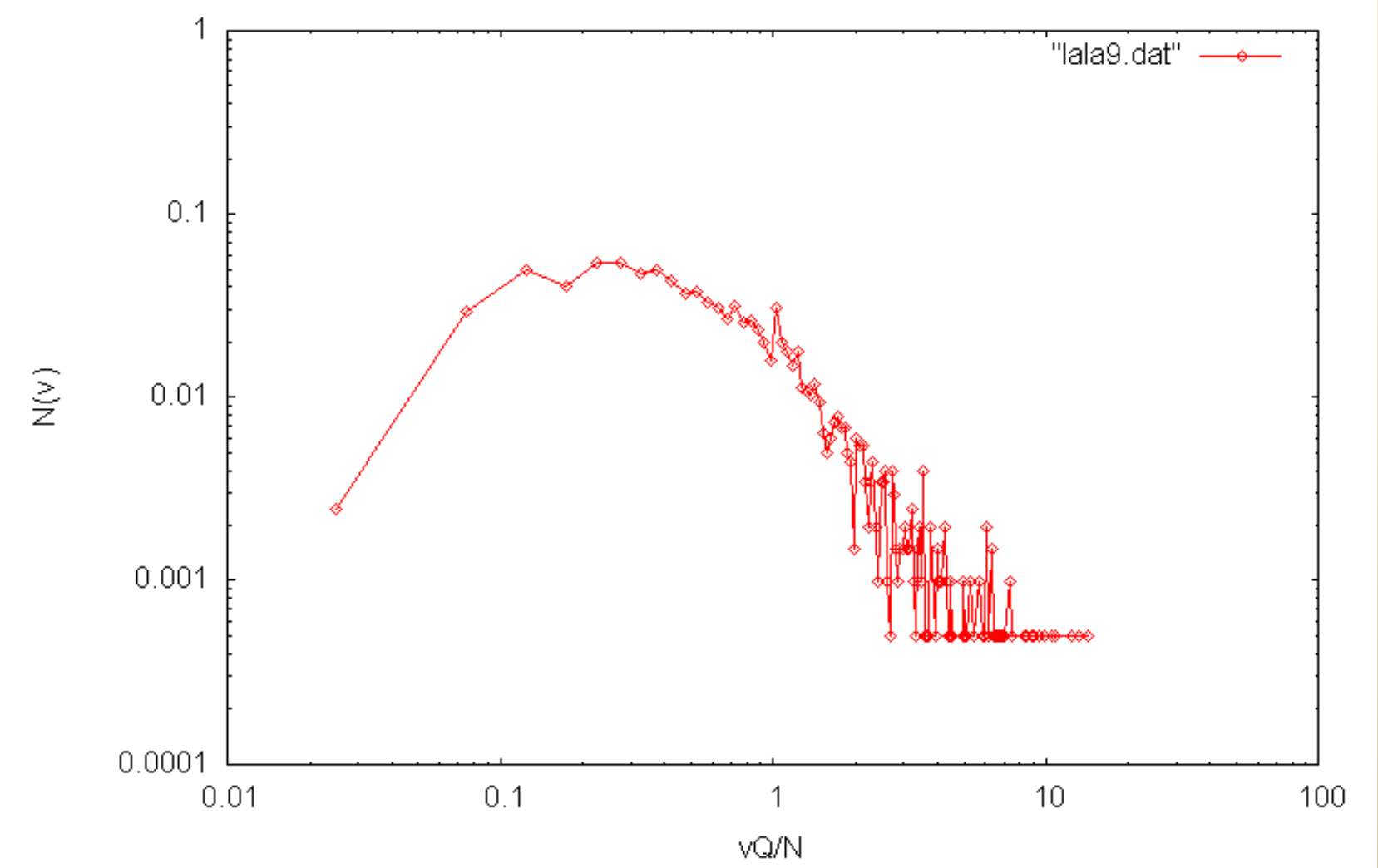
Canada 2004, 2006



Australian 2007



Finland 2003



Distribution of Votes Among Candidates :

For the distribution of votes among candidates, there are at least two types of the voting distribution of elections.

- One is the power-law behavior which has been reported on Brazilian parliamentary elections.
- Another is the lognormal distribution on German, French, Italian and Polish elections.
- We studied the vote distributions of Legislatures in Taiwan and Japan. Their distributions show a mixed behavior of power-law-like and lognormal-like distribution.

我們的工作

- A database of elections(Taiwan, Japan, USA, UK, Finland, Brazil, Canada, Australian…) has been set up.

- A simple growth model is proposed to simulate the opinion propagation in a voter's network.

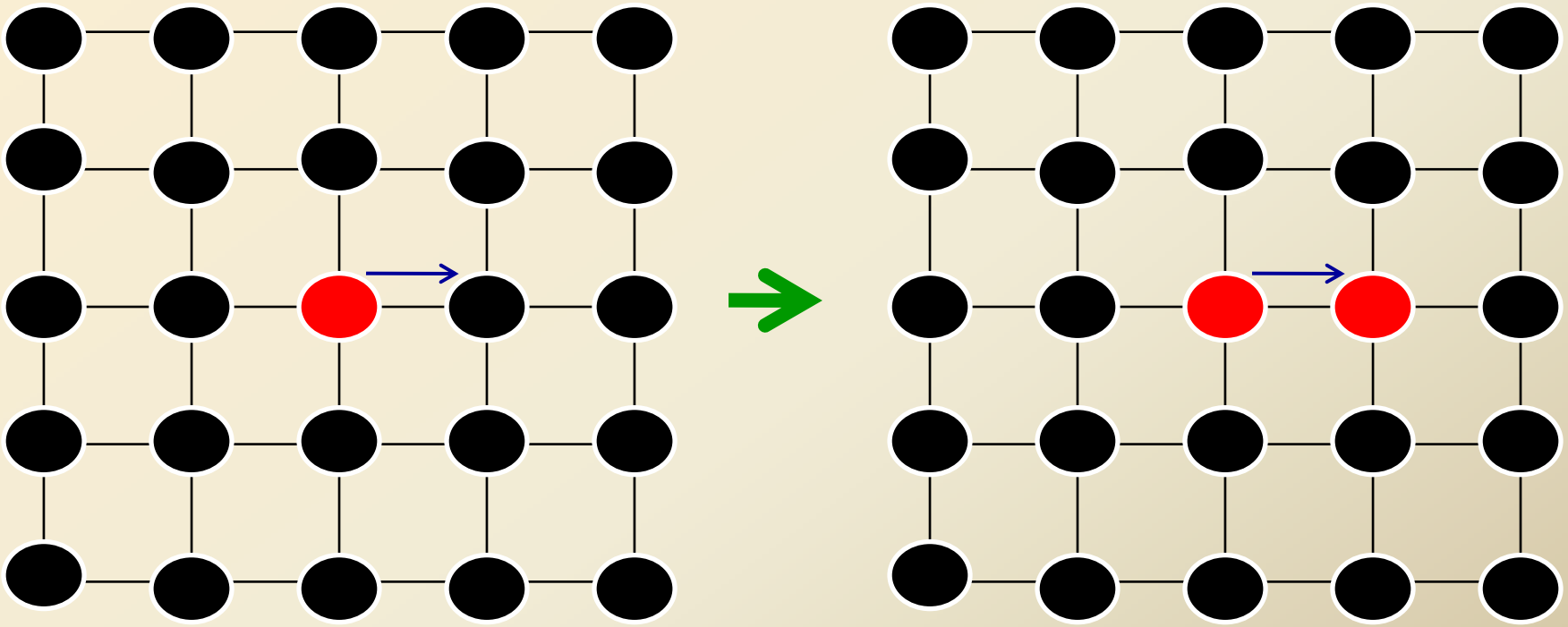
- A better fitting curve is found by analytic approach.

兩個競爭的效應

- 媒體效應 (Media Effect)
- 西瓜效應 (Majority Effect)

模擬

- 以模型模擬在一個投票者網絡中意見擴散的情況。



Simulations

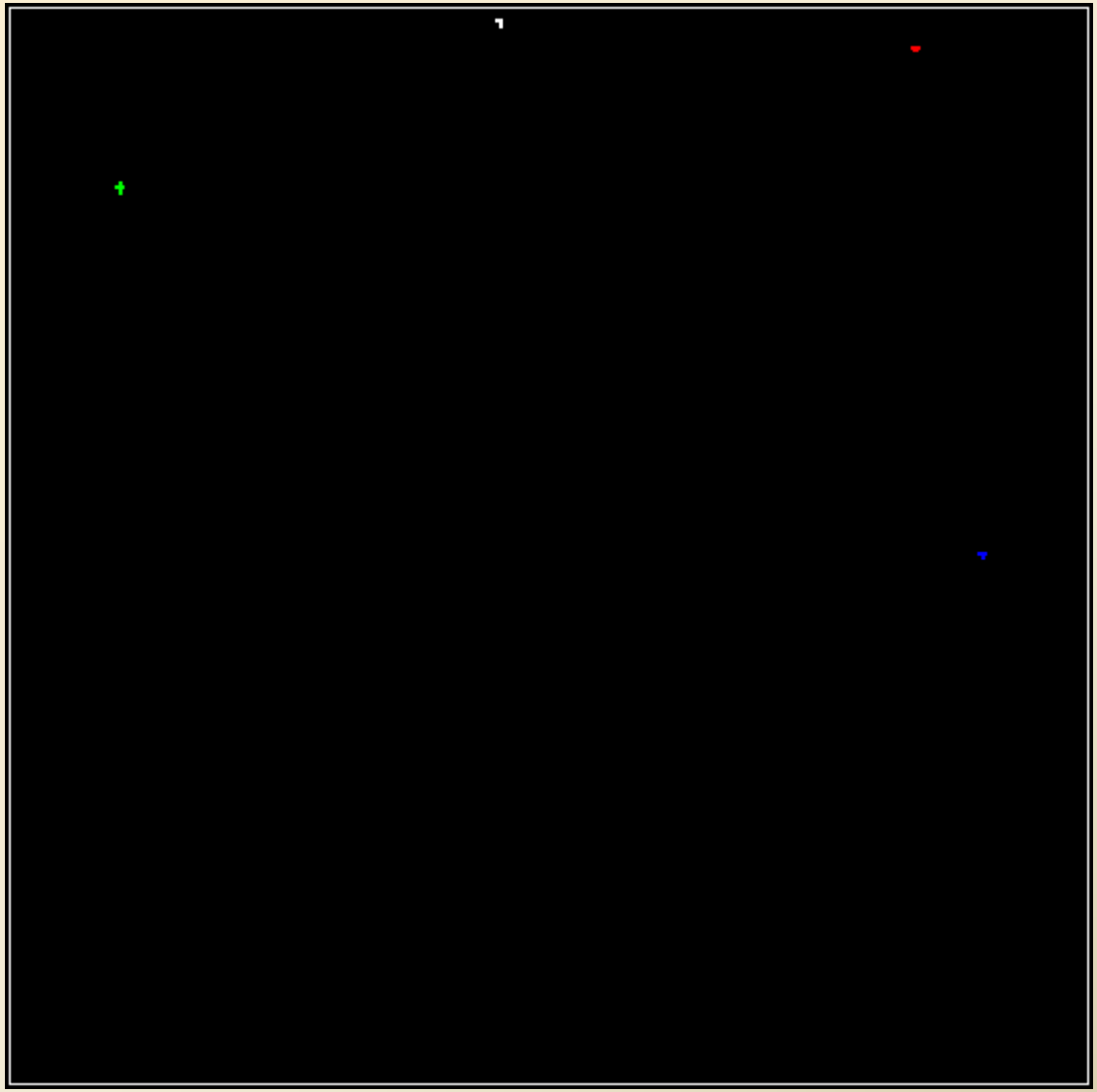
- Two control parameters of distribution (majority effect and media effect) have been studied.
- Majority effect: If a candidate has more supporters (the voters who have chosen this candidate), his/her opinion will diffuse faster.
- Media effect : When a candidate has media promotion, his/her opinion can do a long distance jump.

400*400
Lattice network

160 000
Voters

Total
4 Candidates

2 Candidates
with media effect



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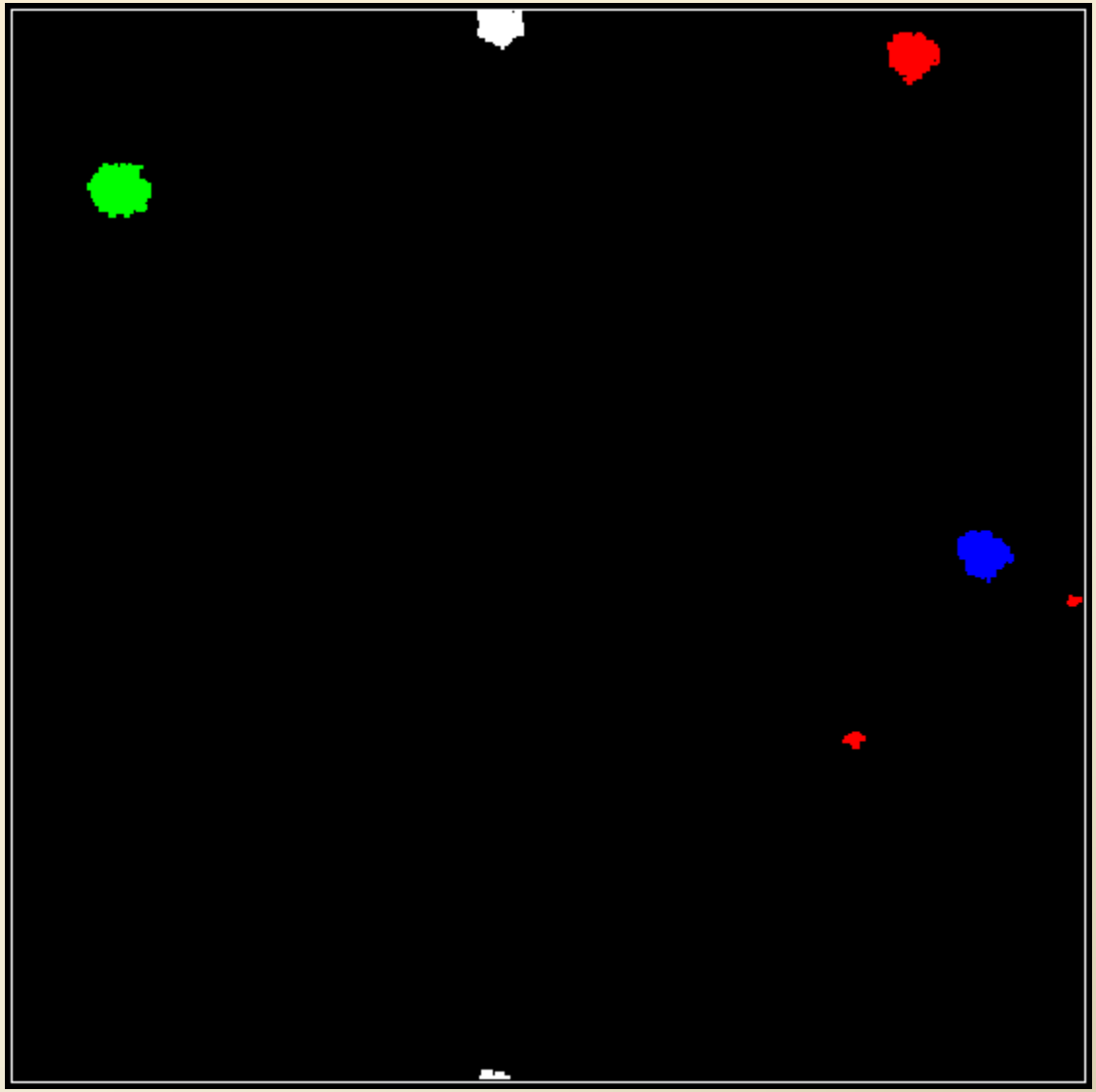

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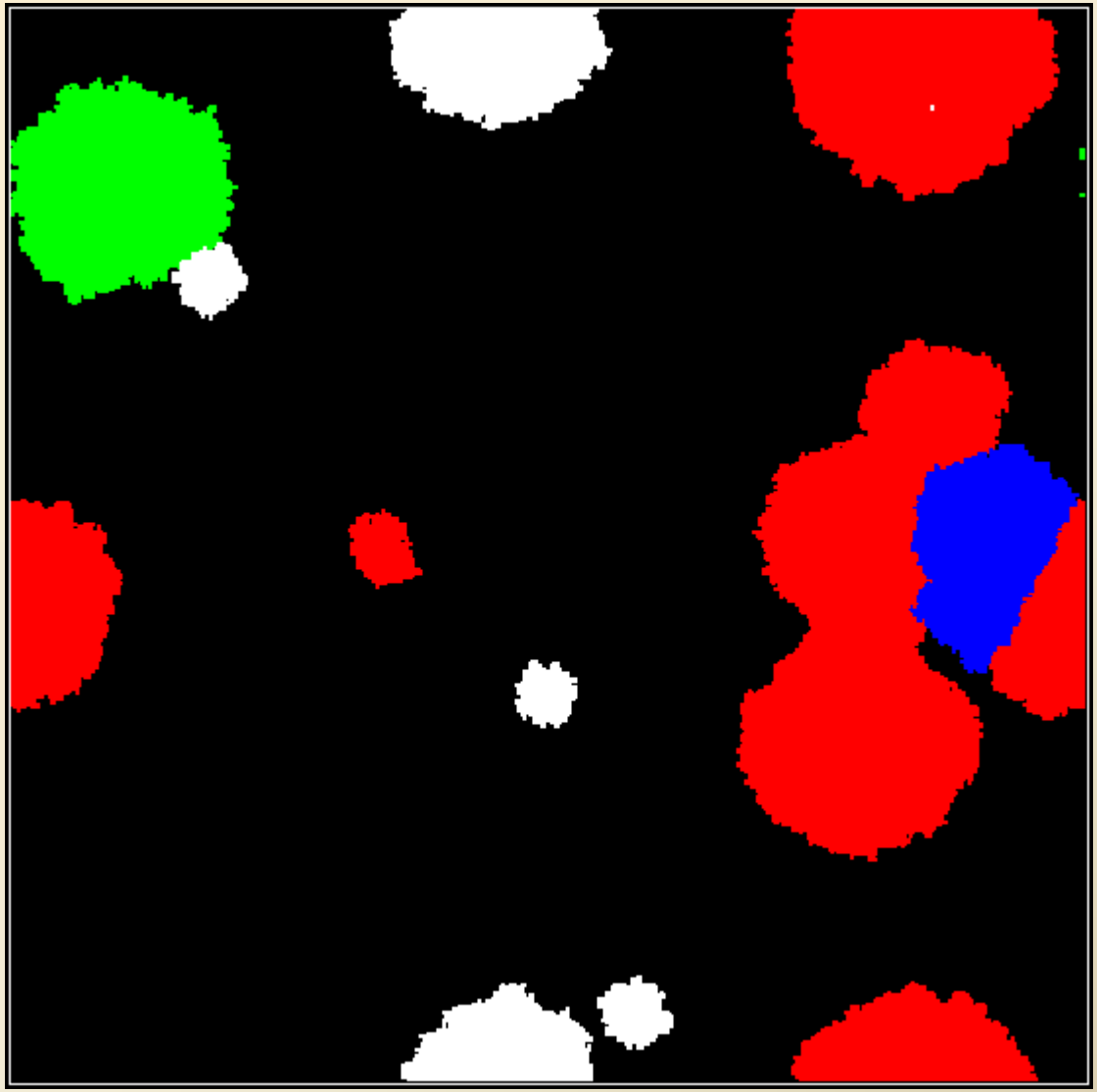
2 Candidates
with media effect

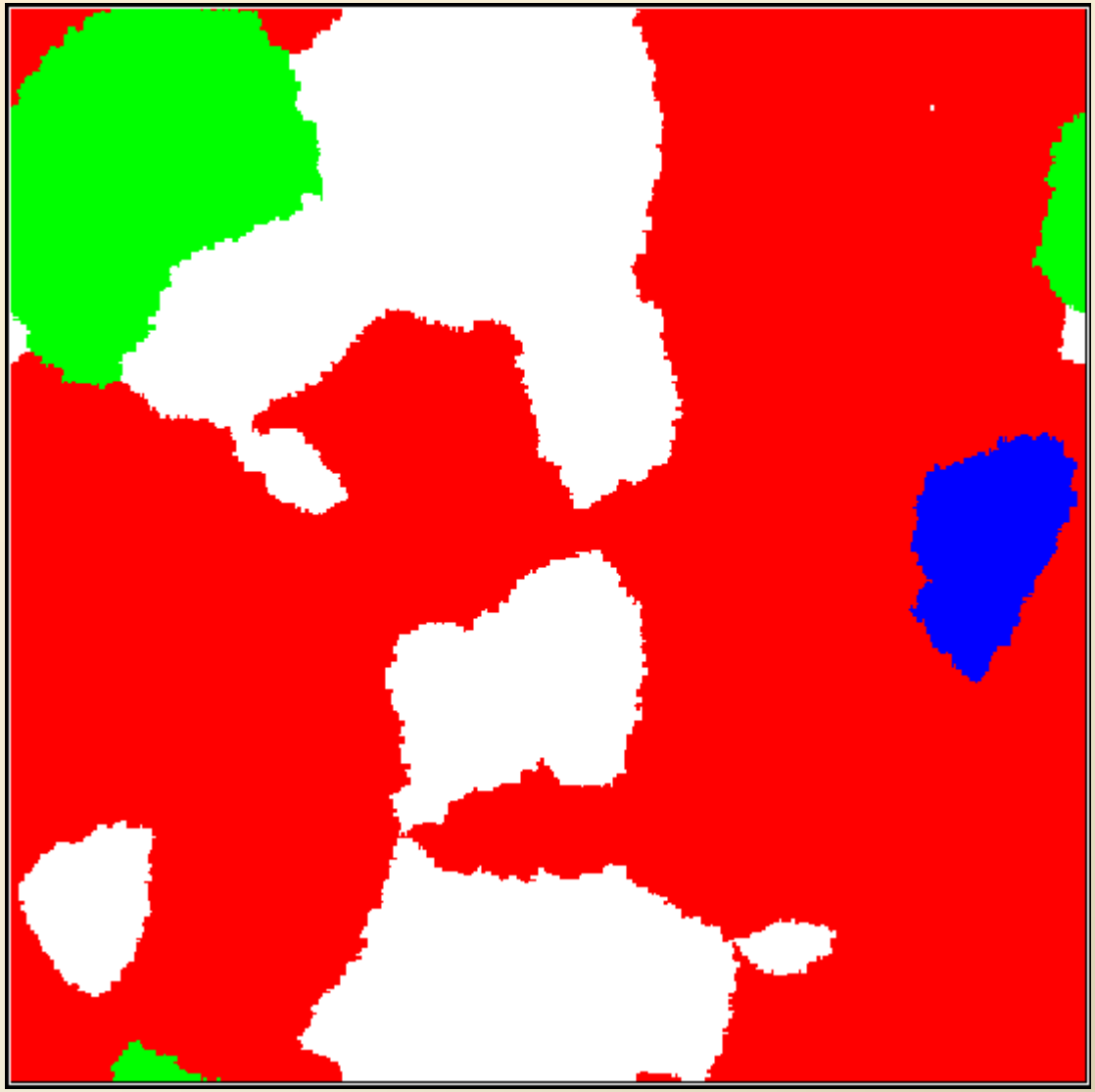


400*400
Lattice network

160 000
Voters

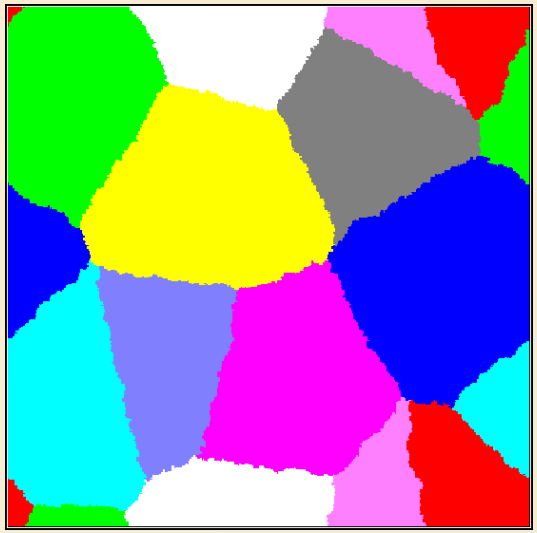
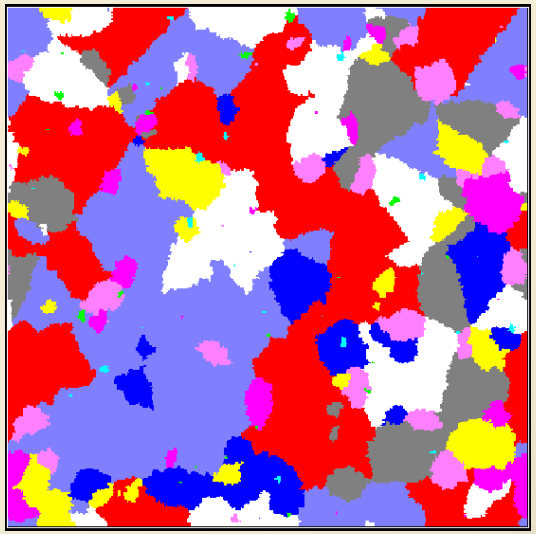
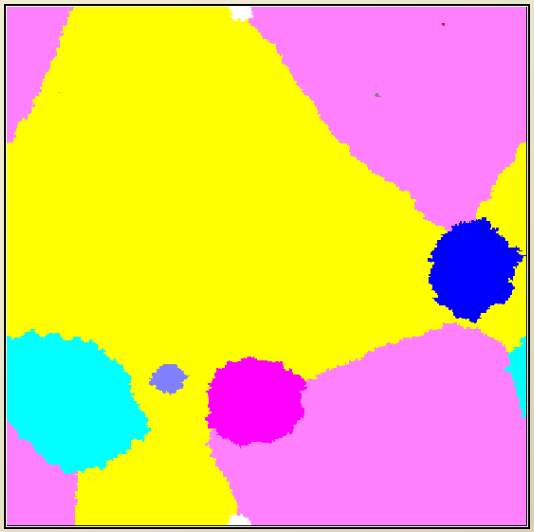
Total
4 Candidates

2 Candidates
with media effect

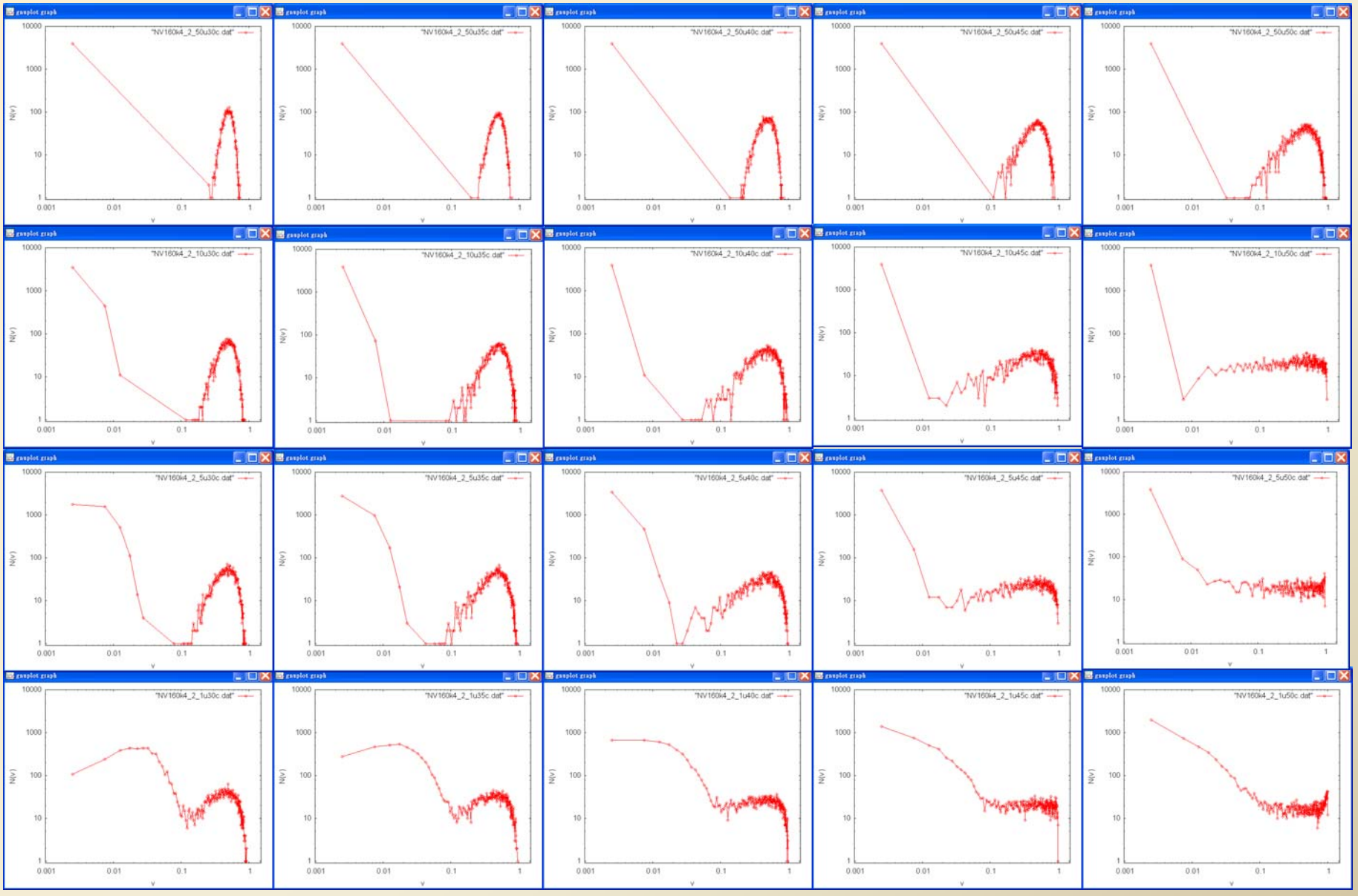


Simulations

- By changing the parameters, we can create a phase diagram, and fit the real world data.

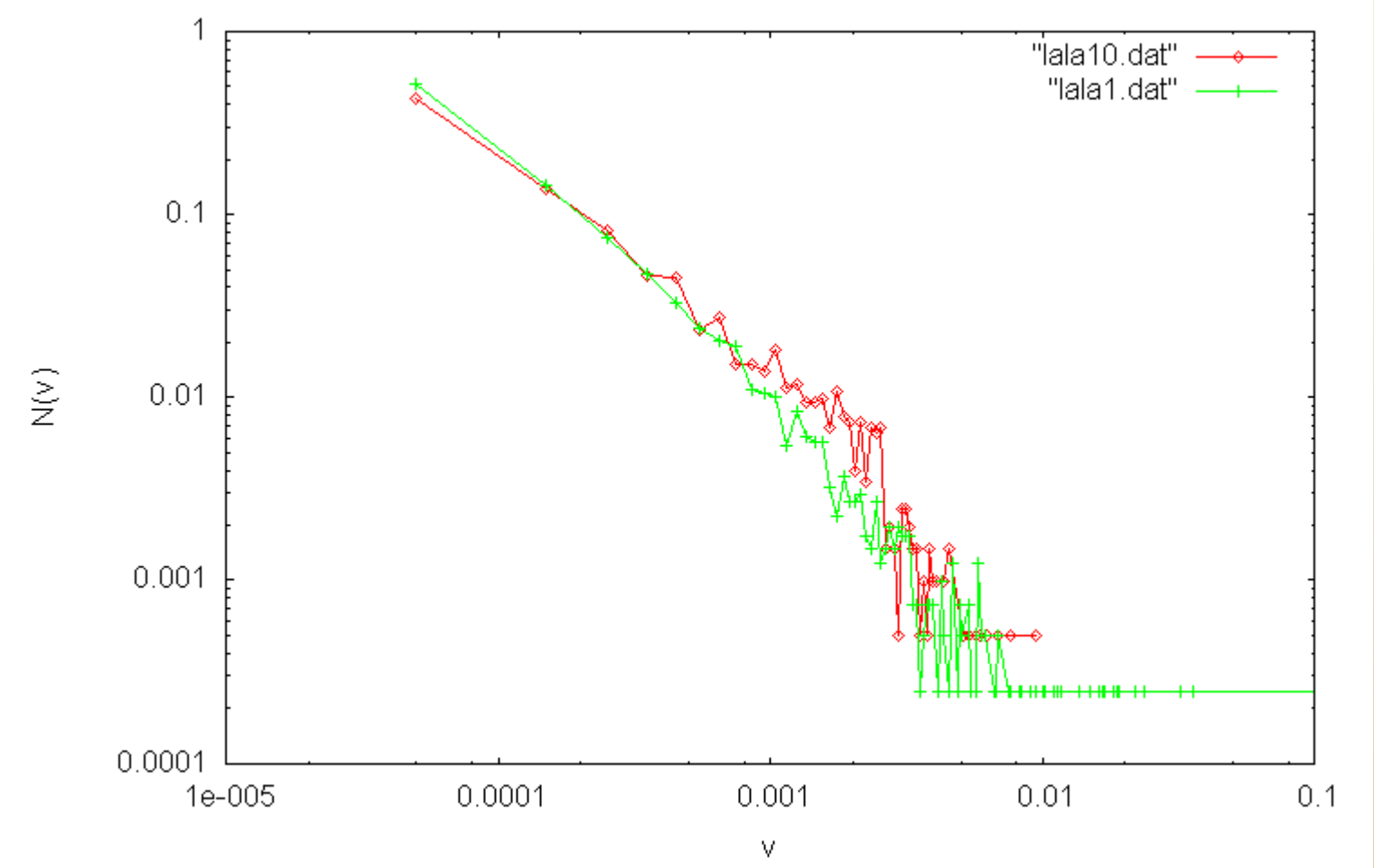




Phase diagram (相圖)



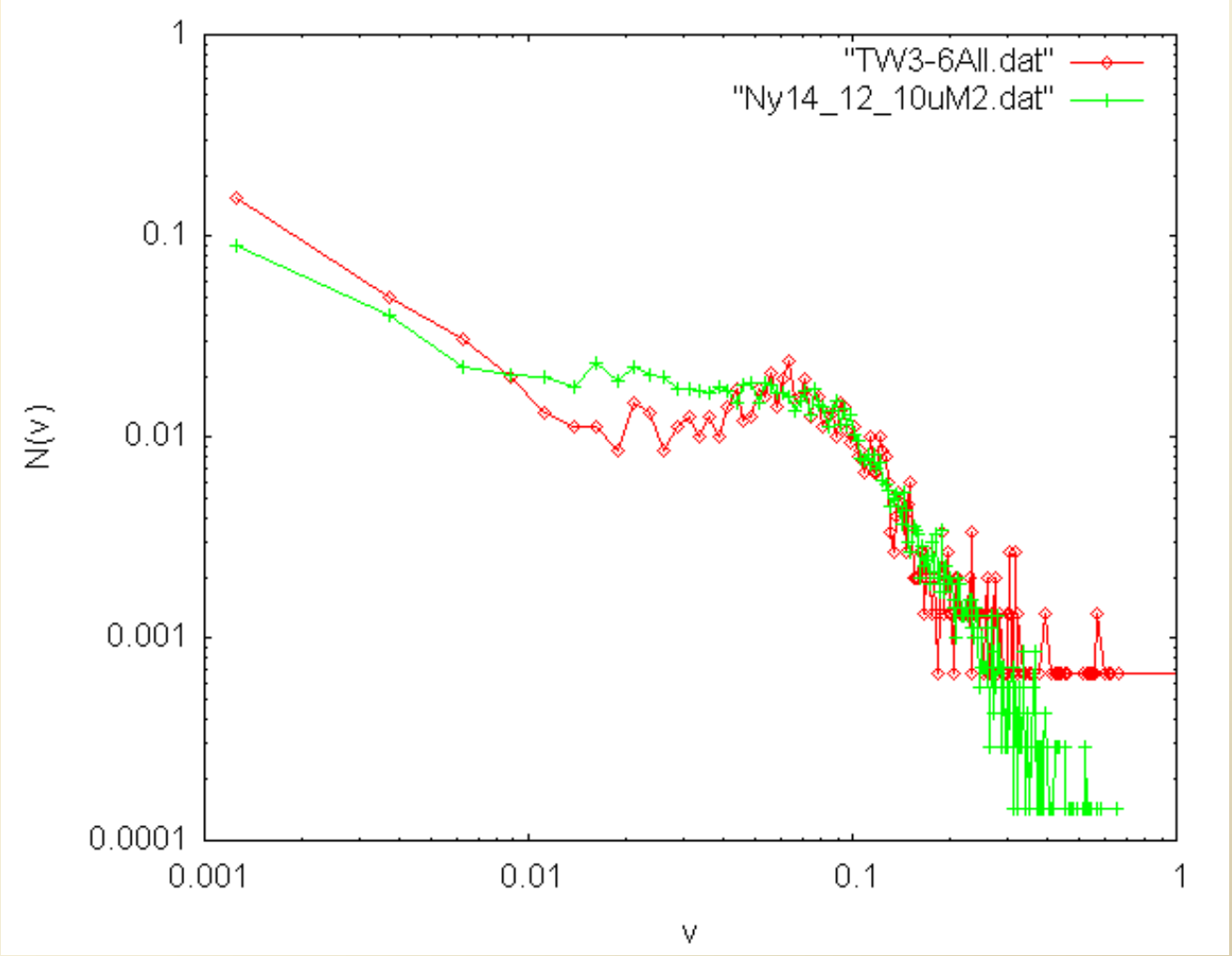
Proportional representation :
multi-member districts and open lists

Finland 2003 (RED),and simulation (GREEN)



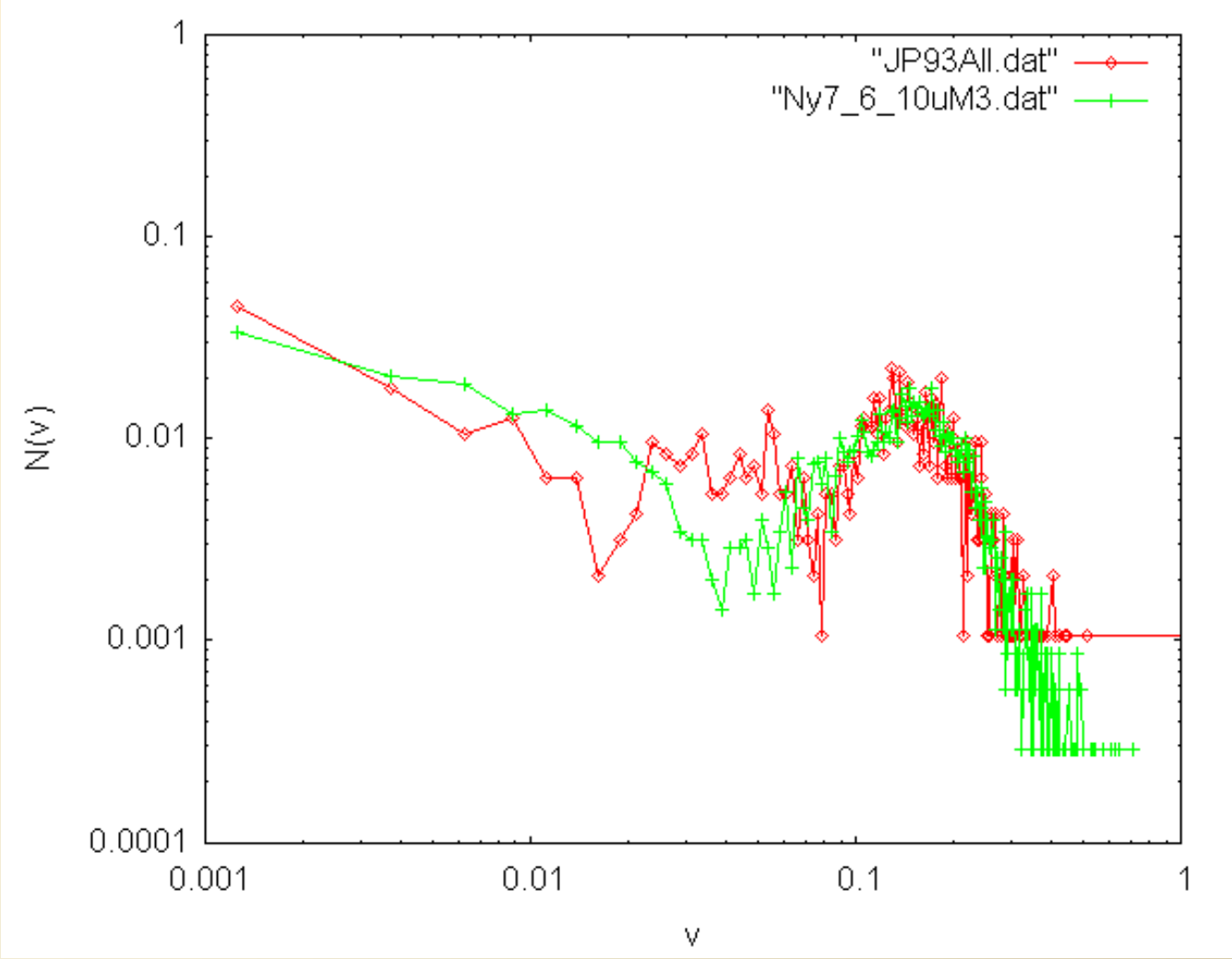
Proportional representation :
single non-transferable vote

Taiwan: Election for the 3-6th Legislative Yuan(**old electoral system**)(RED), and simulation (GREEN)



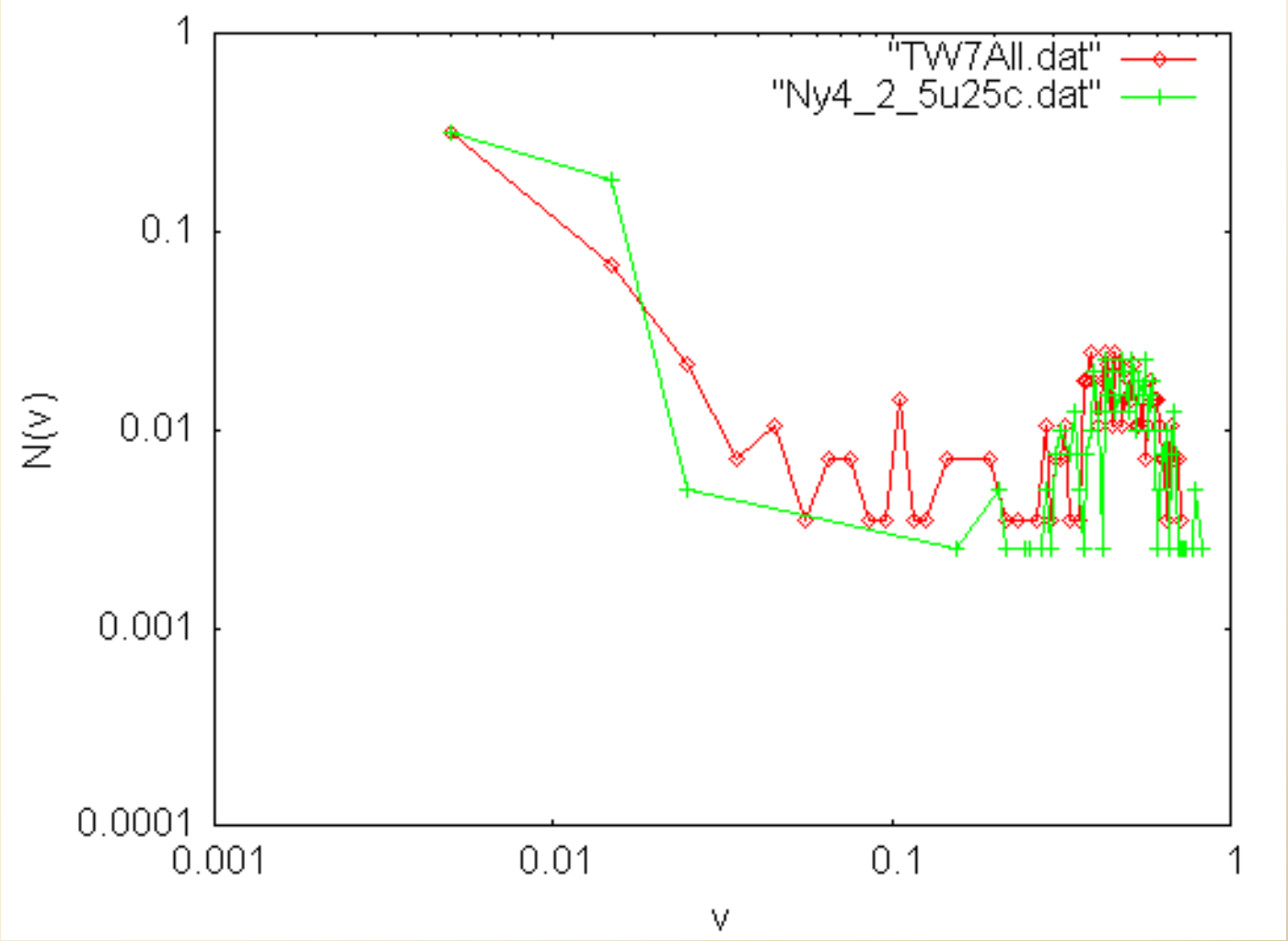
Proportional representation :
single non-transferable vote

Japan: House of Representatives 1993 (**old electoral system**)(RED), and simulation (GREEN)



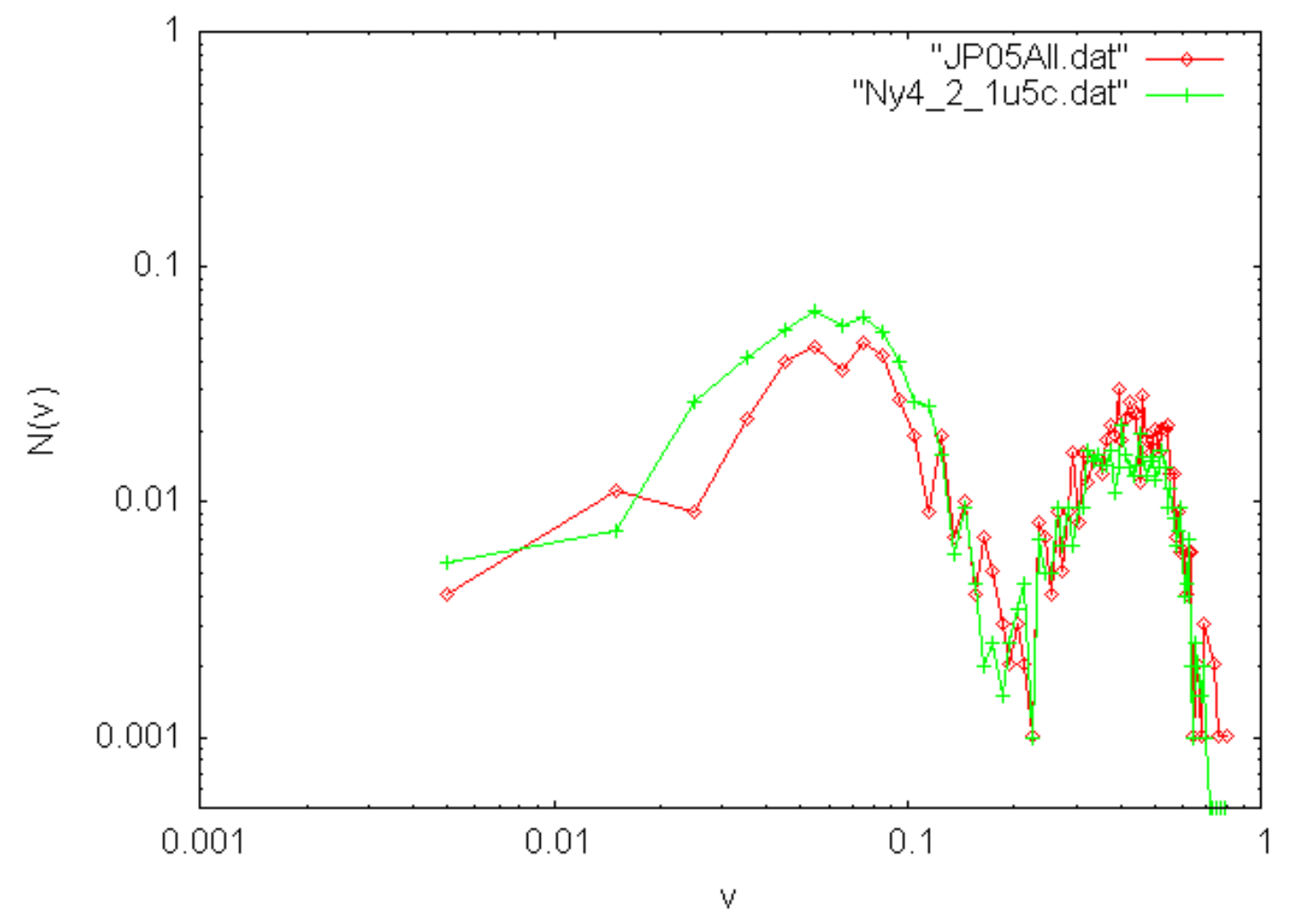
Majoritarian electoral system:

Taiwan: Election for the 7th(2008) Legislative Yuan(**new electoral systems**)(RED), and simulation(GREEN)



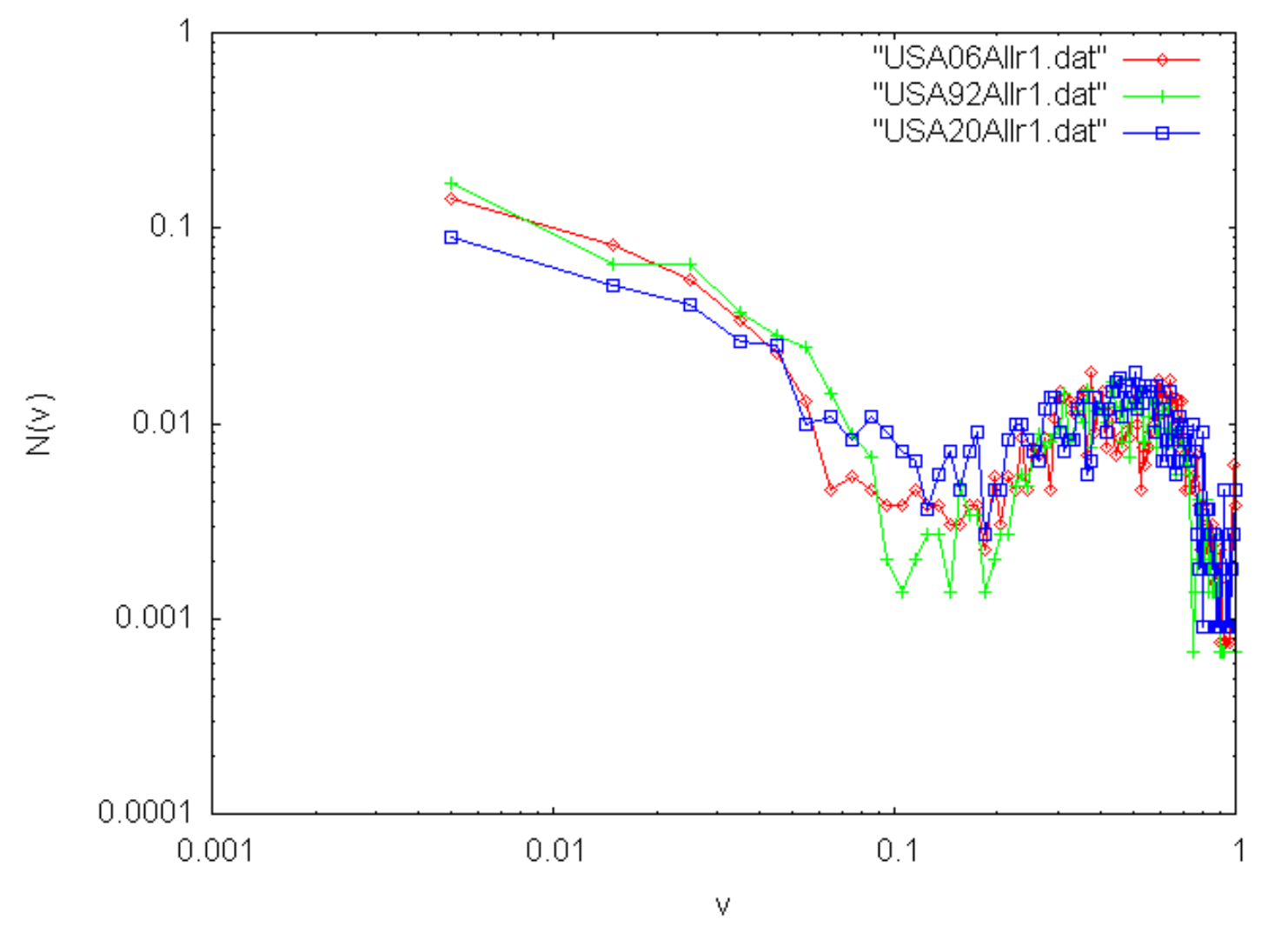
Majoritarian electoral system:

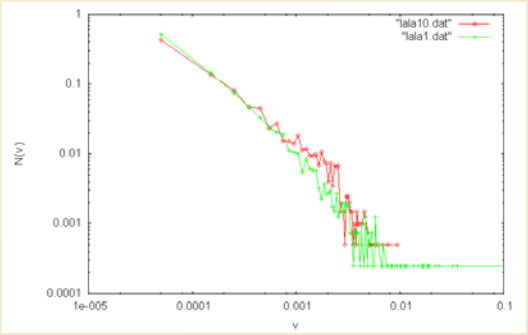
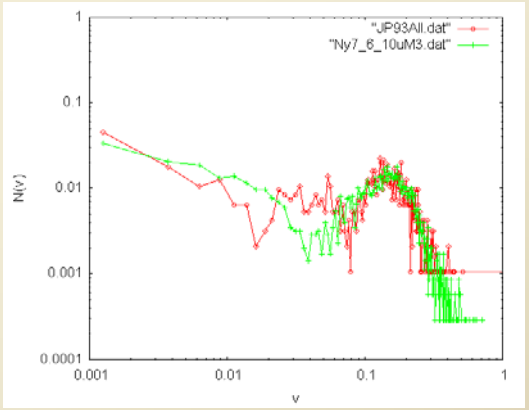
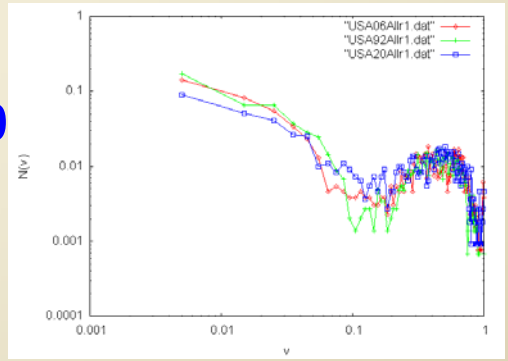
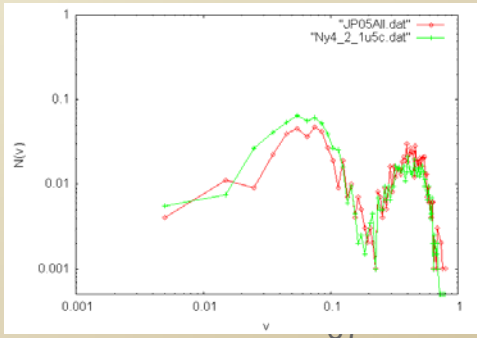
Japan: House of Representatives 2005 (**new electoral system**)(RED), and simulation(GREEN)



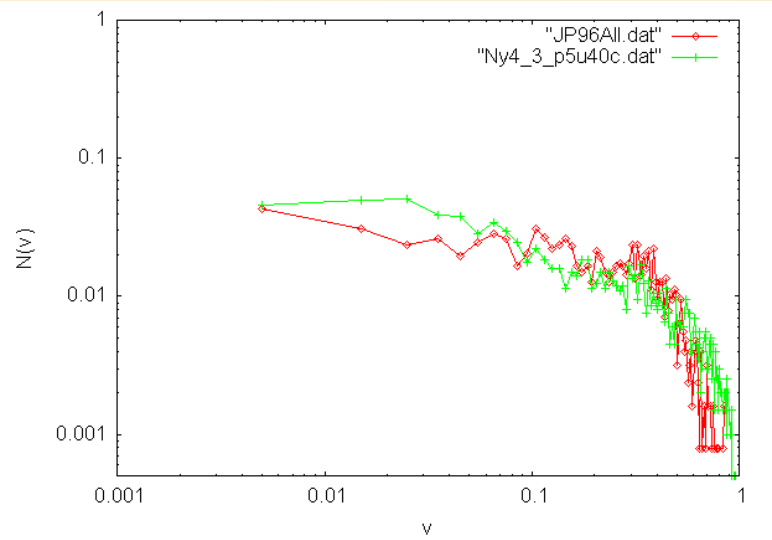
Majoritarian electoral system

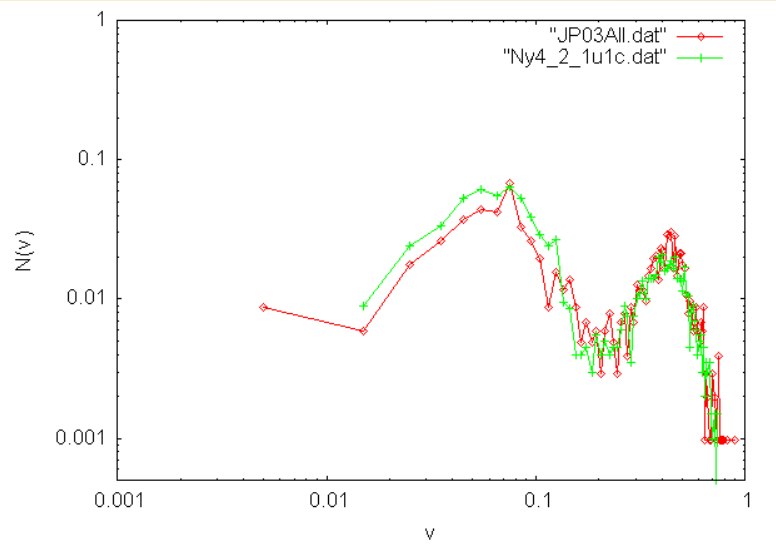
USA Representative:1920(**BLUE**), 1992(**GREEN**), 2006(**RED**)

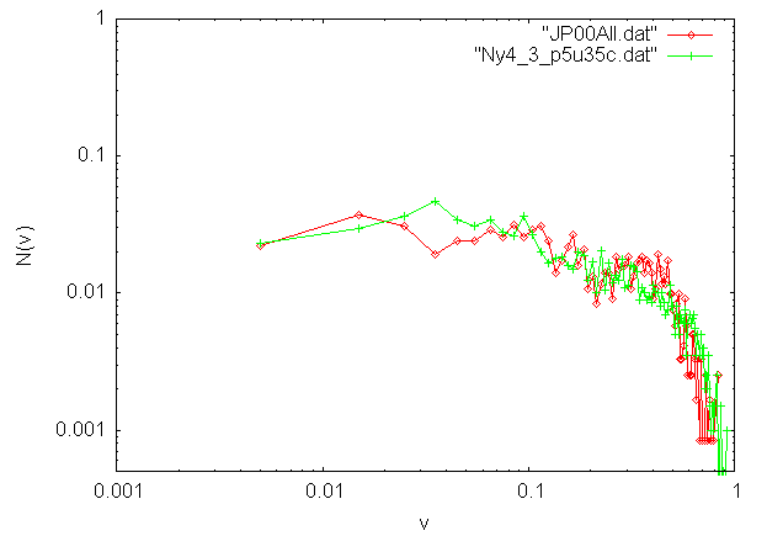


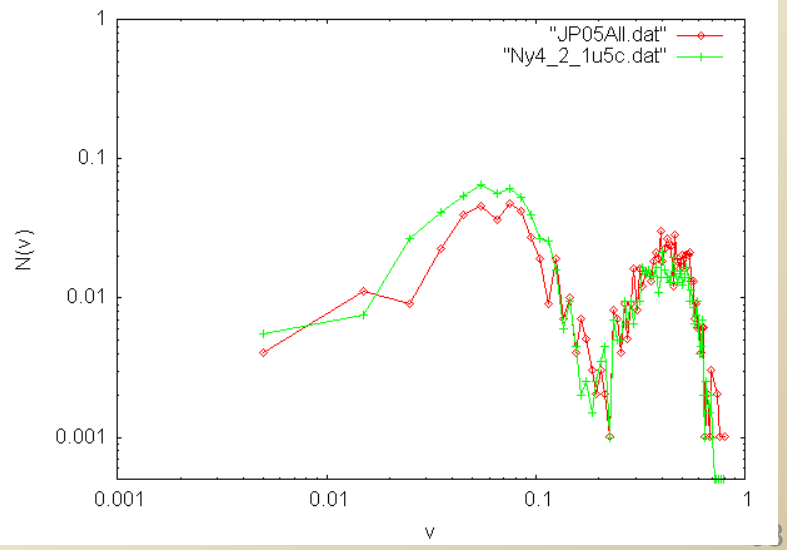
System	Voting district (Voters)	Distribution
Proportional (multi-member , open lists)	**Large** (Voters > **3 000 000**) (candidates > 1000)	
Proportional (single non-transferable vote)	**Medium** (Voters < **500 000**) (candidates < 50)	
Majoritarian electoral system	(Voters < **200 00** (candidates < 10)	 

Japan — Vote Distribution after the New System has been introduced.





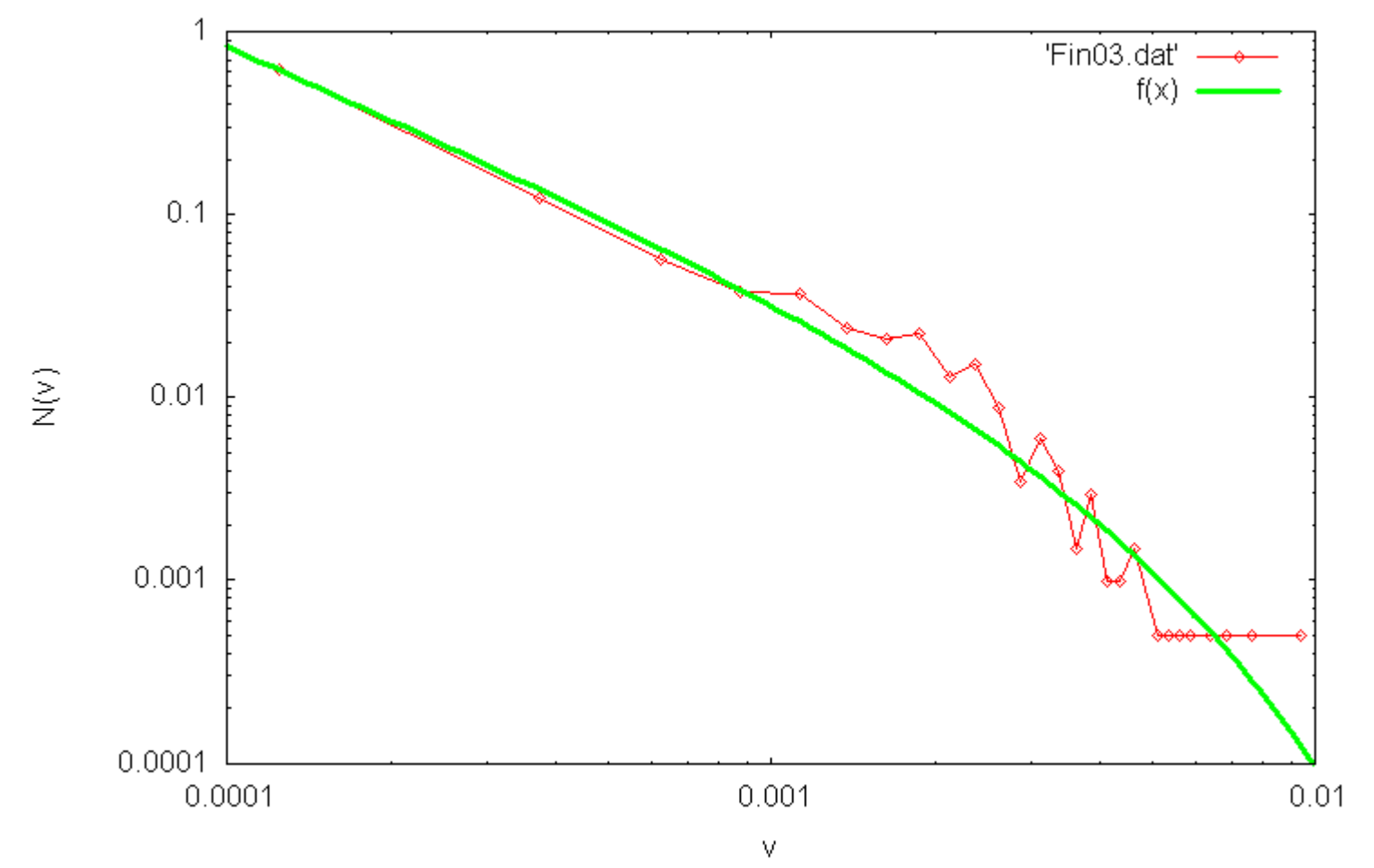




Analytic study

- A better fitting curve been found by using analytic arguments.

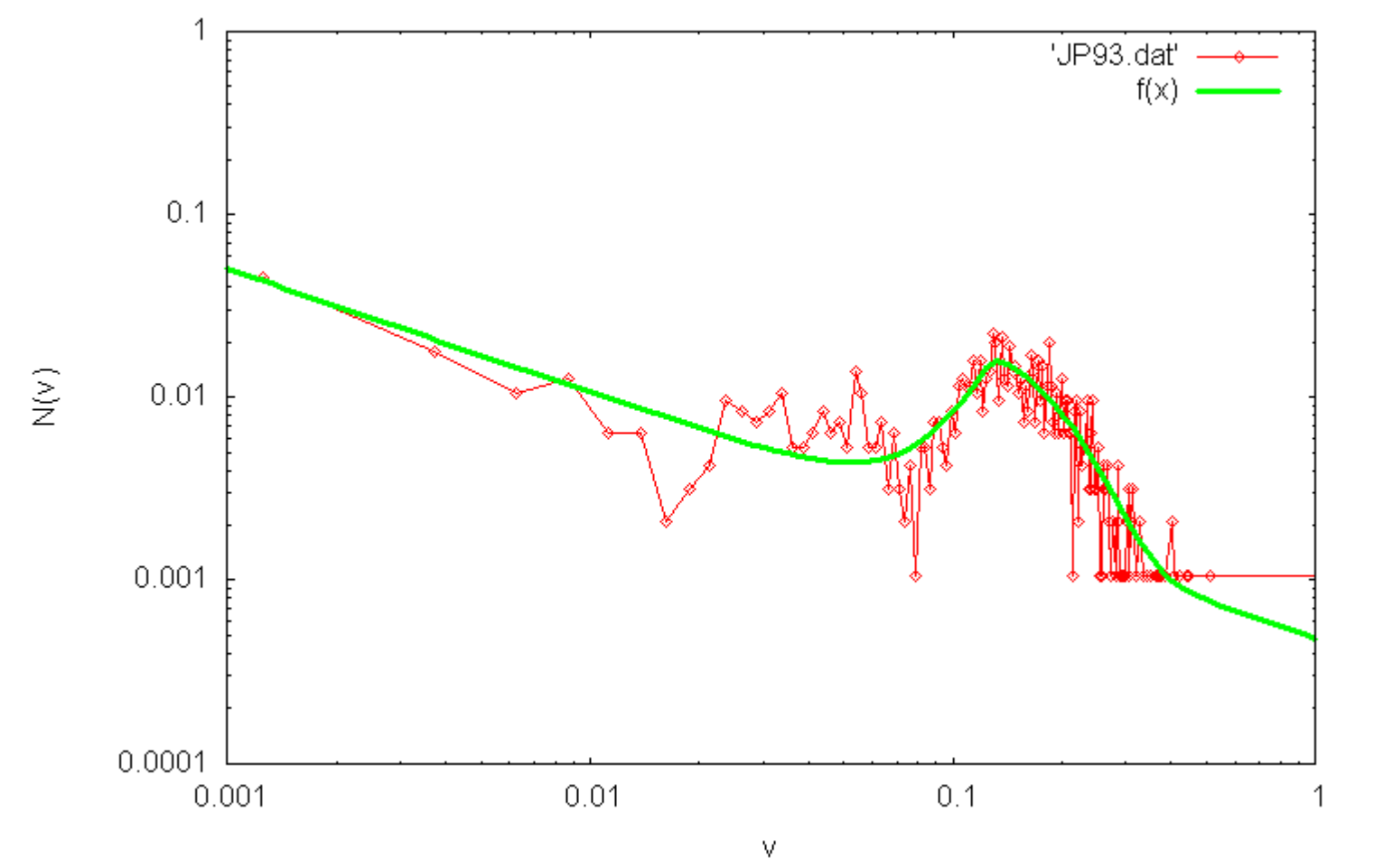
N(v)=a* v**ds0 *exp(-(v-c)**ds1 / (2*b*b));



a = 5.27693e-006 b = 0.0400004 c = 0.0001

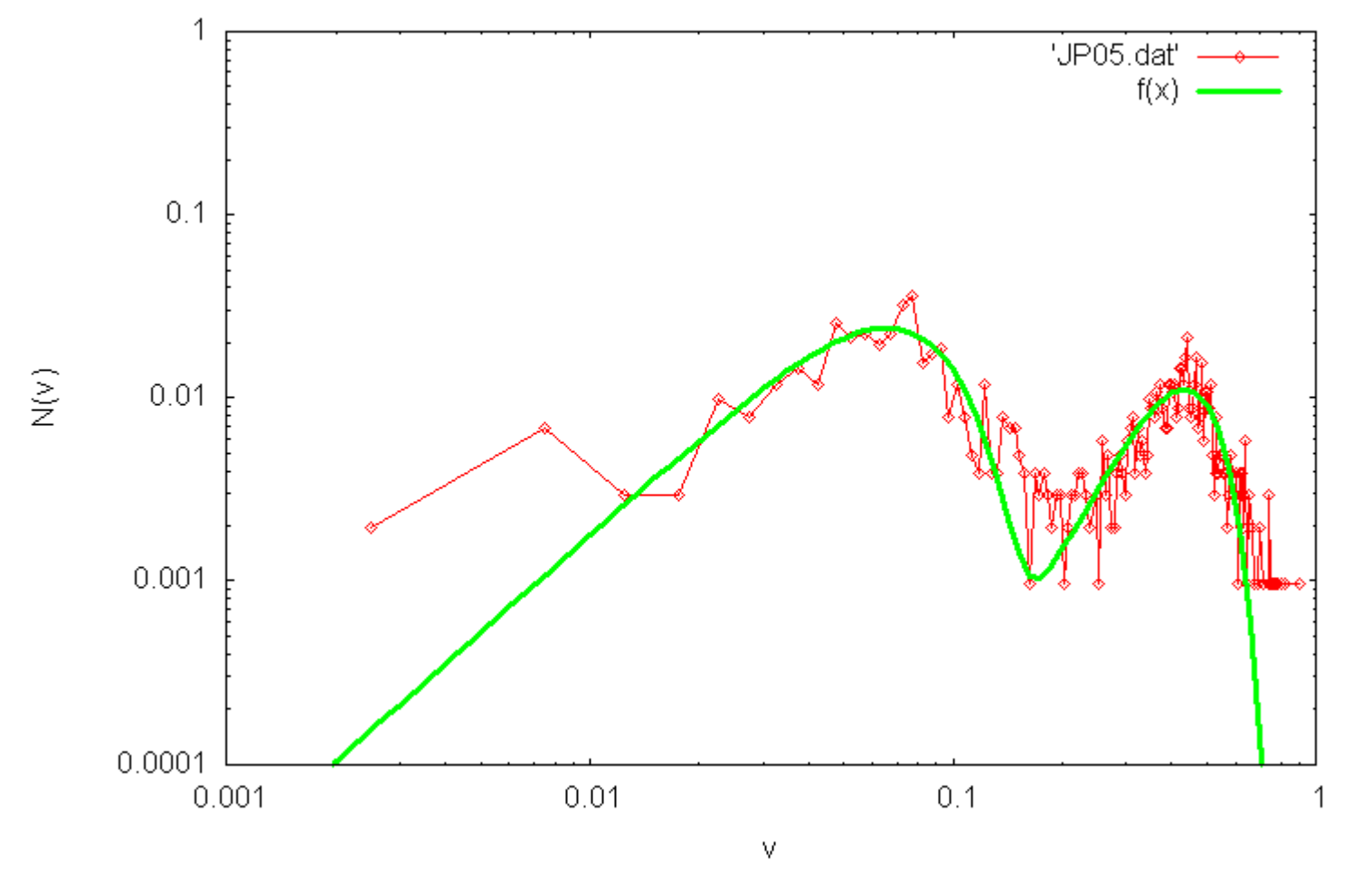
ds1 = 1 ds0= -1.29869

N(v) = a0* v**ds00 *exp(-(v-c0)**ds01 / (2*b0*b0))
+ a1* v**ds10 *exp(-(v-c1)**ds11 / (2*b1*b1))



a0= 4.8118 E-4 b0= 7.1982 c0= 0.83975 ds00 = -0.67427 ds01= 2.3938
a1= 0.25859 b1= 0.13189 c1= 0.12869 ds10 = 1.41862 ds11= 1.1543

N(v) = a0* v**ds00 *exp(-(v-c0)**ds01 / (2*b0*b0))
+ a1* v**ds10 *exp(-(v-c1)**ds11 / (2*b1*b1))

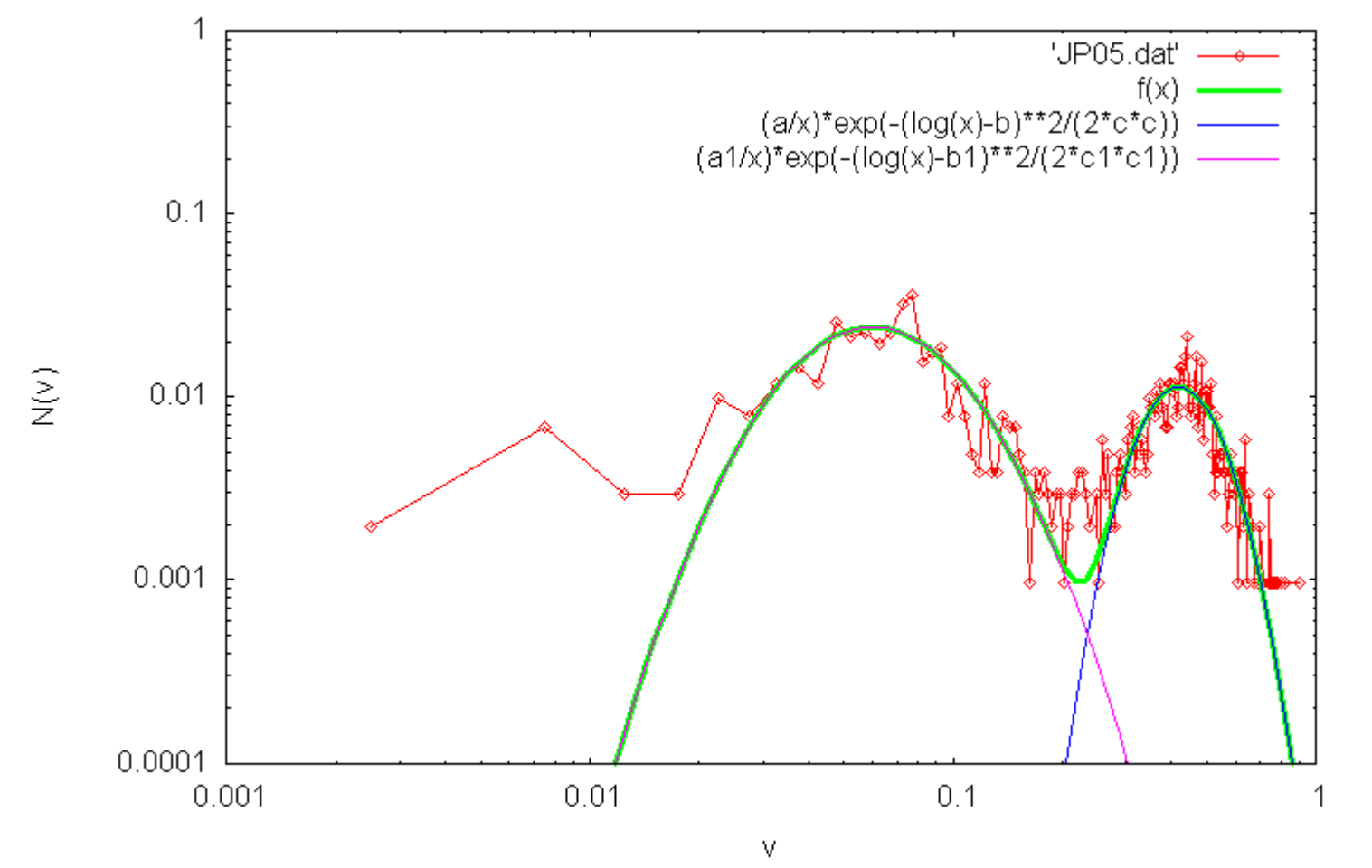


a0= 6.2272 b0= 0.0298578 c0= 0.00010 ds00 = 1.77408 ds01= 2.4424

a1= 0.382389 b1= 0.114112 c1= 0.00010 ds10 = 3.40941 ds11= 4.80632

Lognormal distribution

$$N(v) = (a/v)*\exp(-(\log(v)-b)^{**}2/(2*c*c)) + (a1/v)*\exp(-(\log(v)-b1)^{**}2/(2*c1*c1))$$



a = 0.0049103 b = -0.817491 c = 0.233392

a1 = 0.00163099 b1= -2.57677 c = 0.48974

Summary on Distribution of Votes

- The type of votes distribution depends on the electoral systems(Proportional representation (Open Party list system(OPPR), Single non-transferable vote (SNTV)), Majoritarian electoral system(MES)).
- A simple growth model can simulate these distributions by changing control parameters.
- A better fitting curve is found by analytic approach.

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