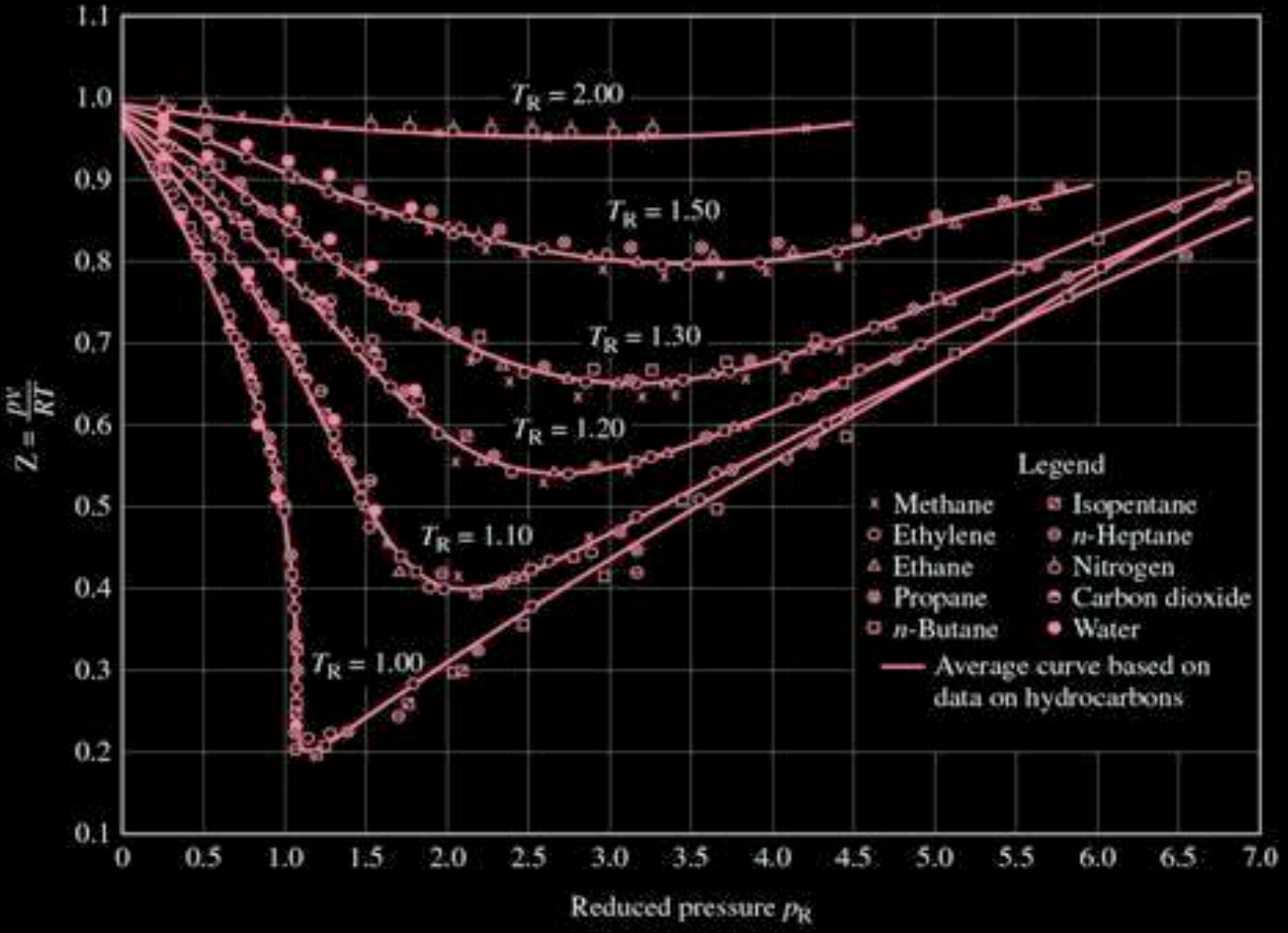
Towards a physics of society

Santo Fortunato

Outline

- Prologue
- Building a phenomenology:
  1) voting behavior
  2) citation behavior
- Outlook

“Measure what is measurable, and make measurable what is not so…”



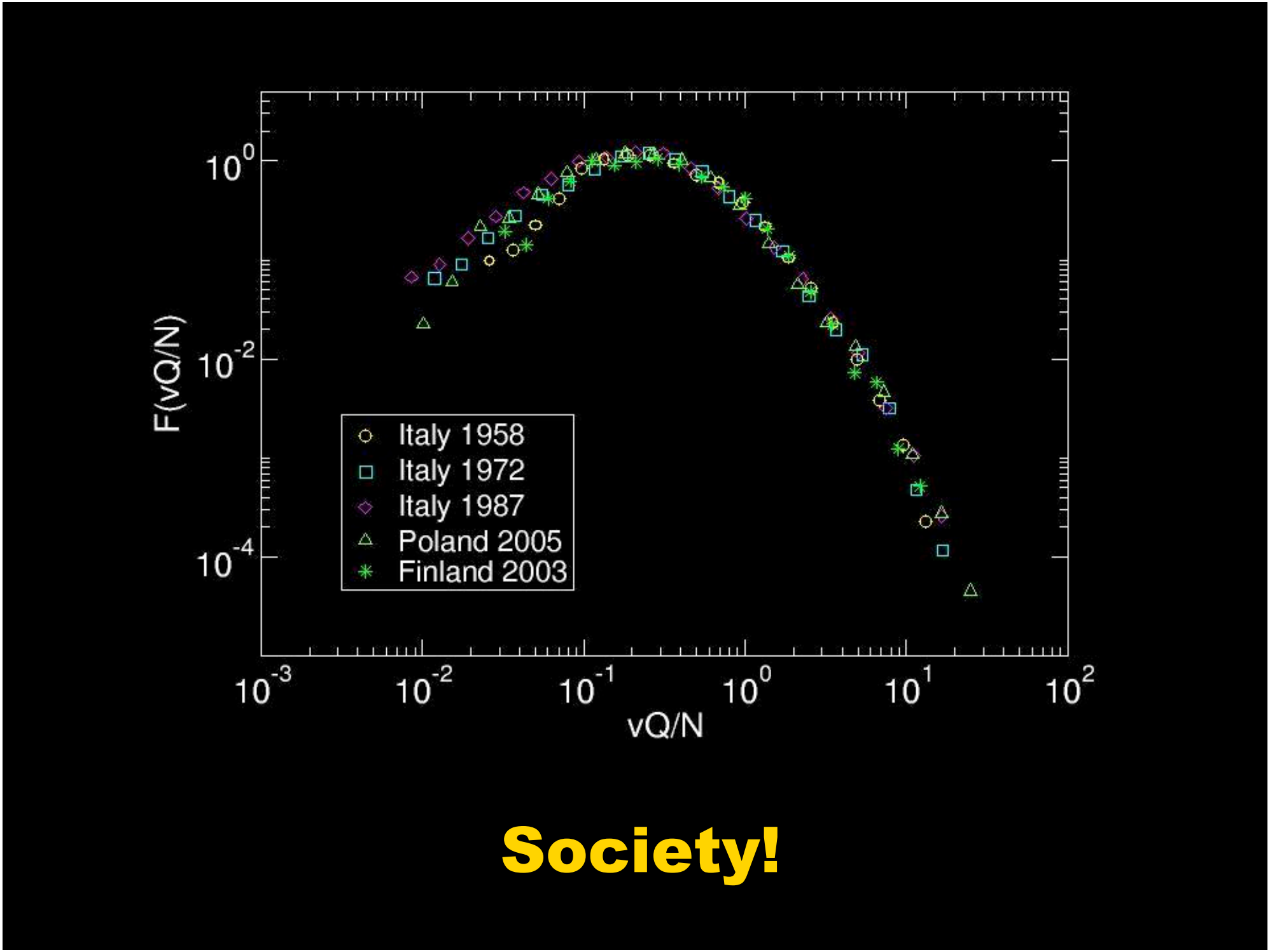
$$T_r = \frac{T}{T_c}$$

$$P_r = \frac{P}{P_c}$$

$$V_r = \frac{V}{V_c}$$

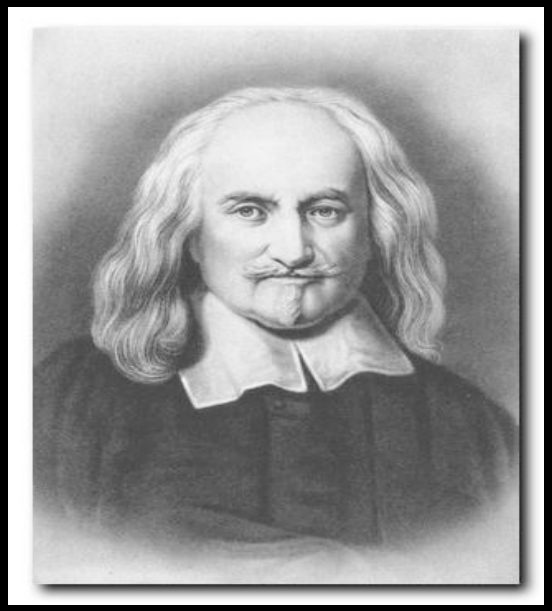
Normalization

Physics

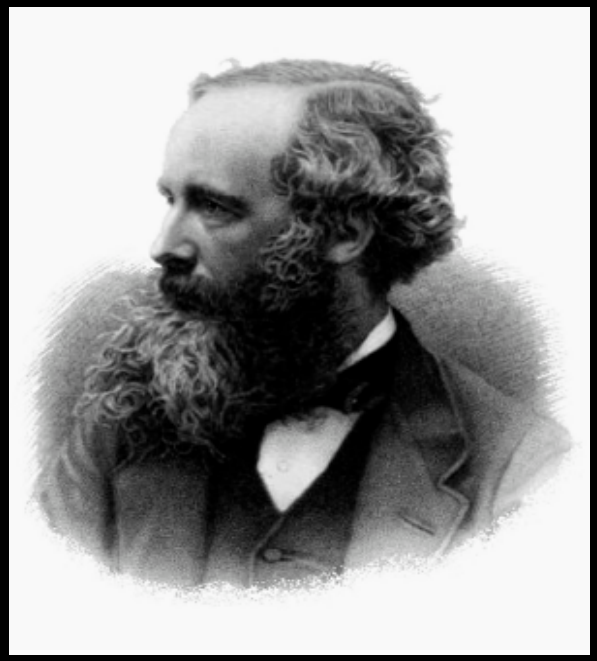

F(vQ/N)
vQ/N
Italy 1958
Italy 1972
Italy 1987
Poland 2005
Finland 2003

Society!

History



Social statistics: number of births, deaths, crimes, suicides, etc.



From Newtonian mechanics of particles to statistical mechanics to describe gases

Sociophysics

From individuals that interact *locally* to collective behavior and organization.

Risky business!

People are not atoms: their interactions are not reproducible!

Necessary condition: the size of the social groups must be big (large scale behaviour)

In this way, the phenomena won’t be much affected by individual features

Interesting aspects for statistical physicists:

- **Large-scale regularities: scaling**
- **Universal features**
- **Microscopic origin of macroscopic behaviour**

Quantitative understanding!

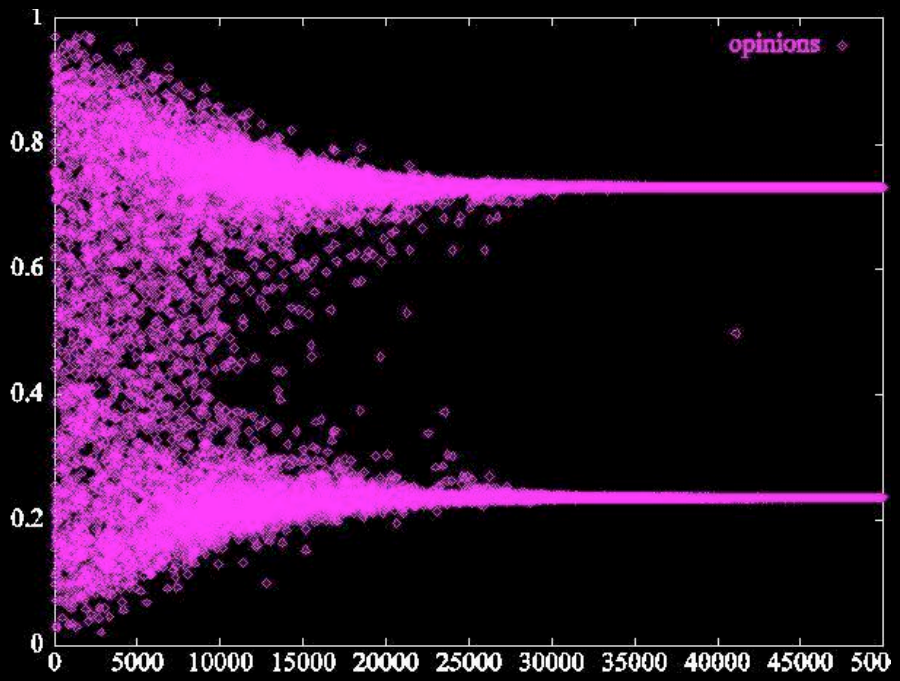
Opinion dynamics

Deffuant et al.(2000)

Opinions are real-valued.

Bounded confidence: opinions need to be close to affect each other

Evolution to one, two or more opinions



Questions

- **Shall we content ourselves with such a qualitative description?**
- **Is it possible to validate this approach?**

Building a phenomenology of social dynamics

Quantitative characterization of large scale social phenomena

- **Voting behavior**
- **Citation behavior**

Elections

- **Large scale social phenomenon**
- **Lots of available data**

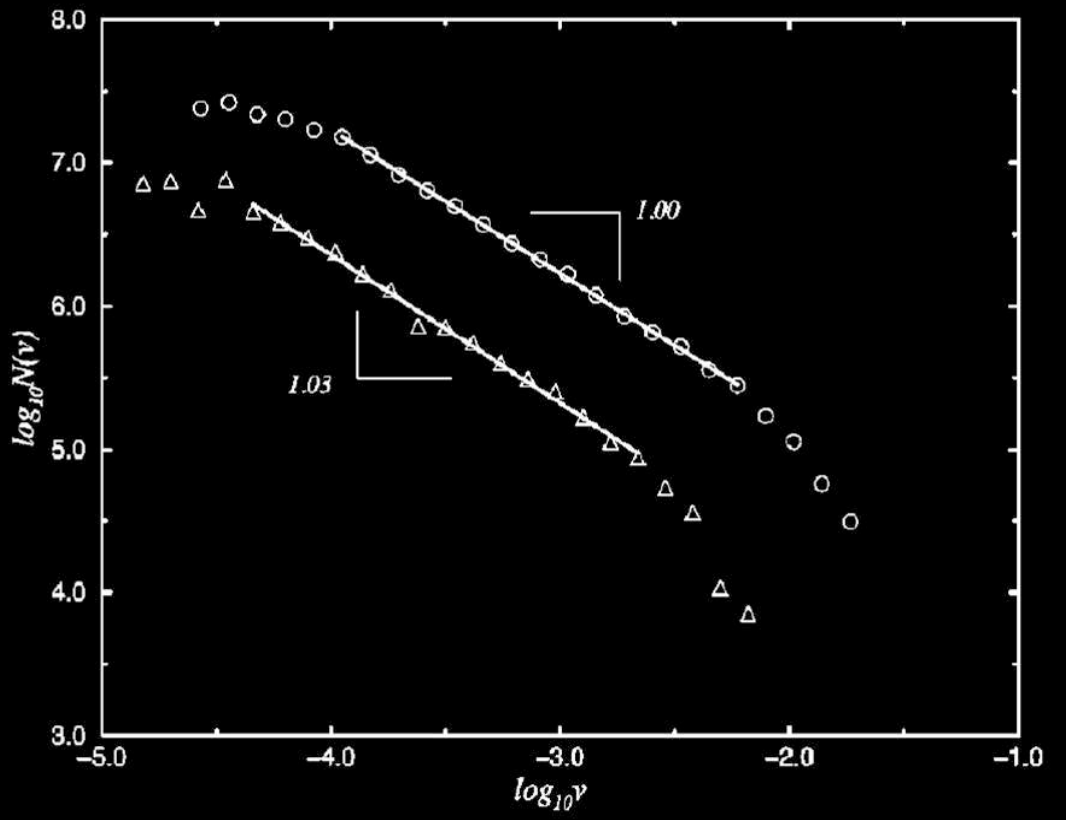
Elections

State elections in Brazil 1998 (Costa Filho et al., PRE, 1999)

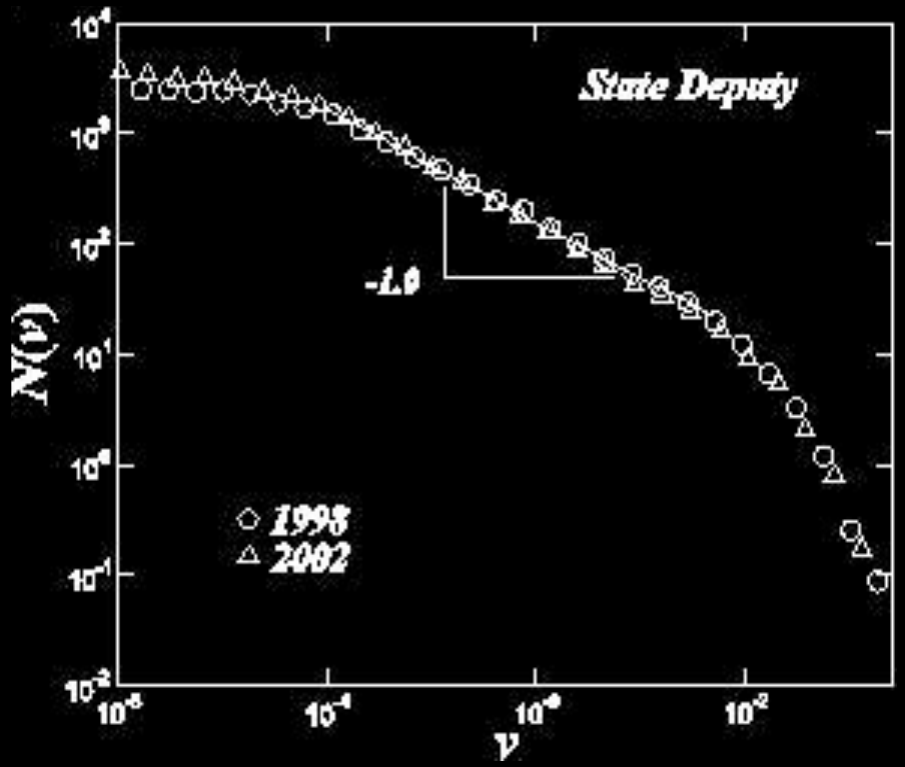
v = # votes received by a candidate

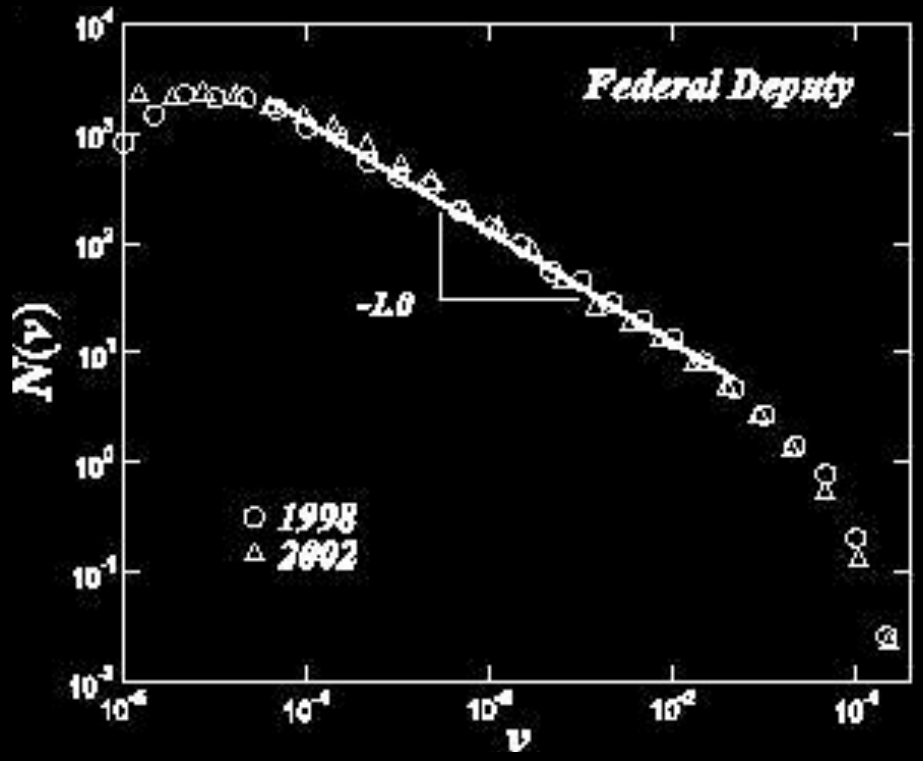
Focus: distribution of v across all candidates

1/v behavior



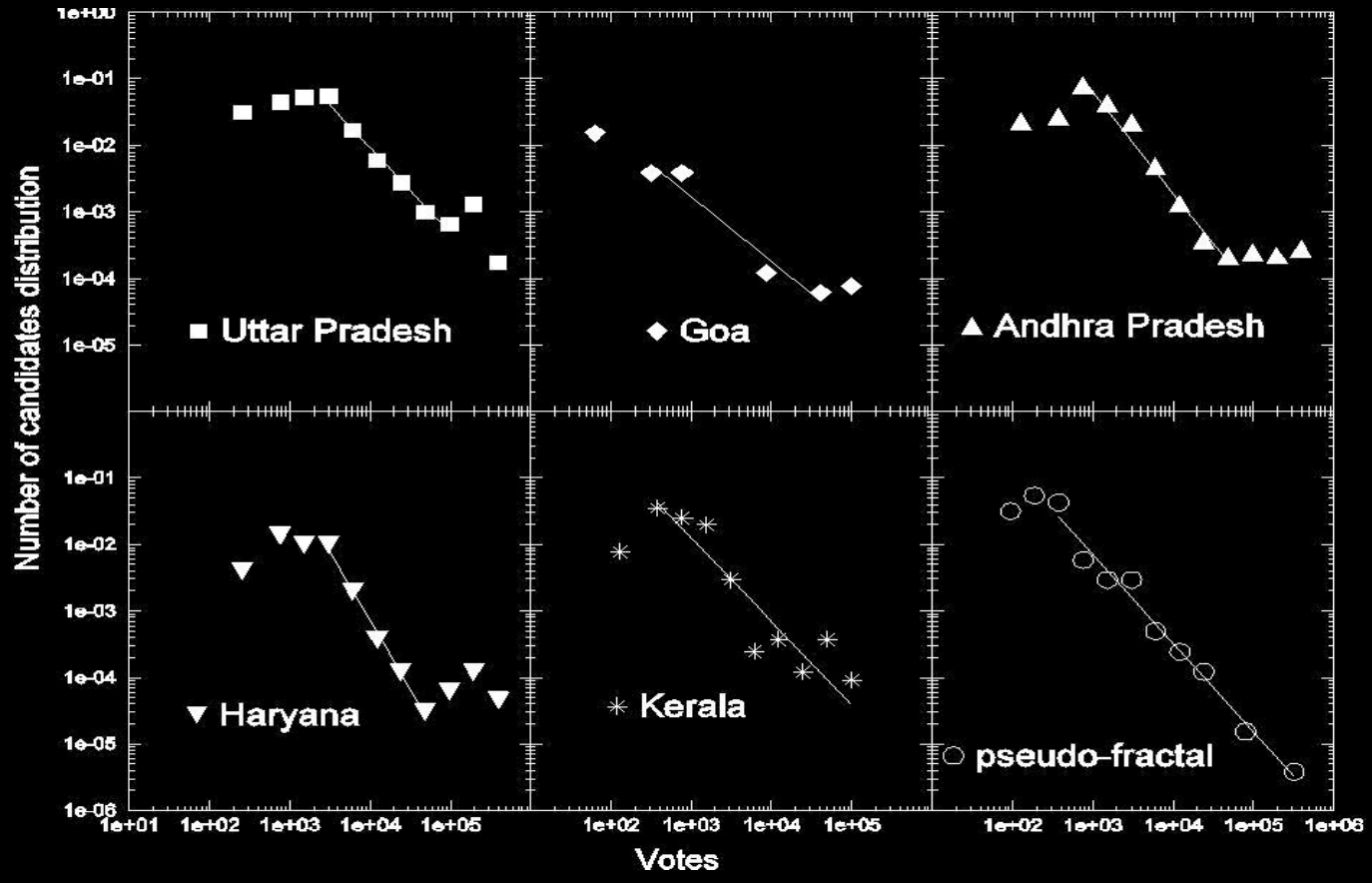
Elections in Brazil 2002
(Costa Filho et al., Physica A 2003)



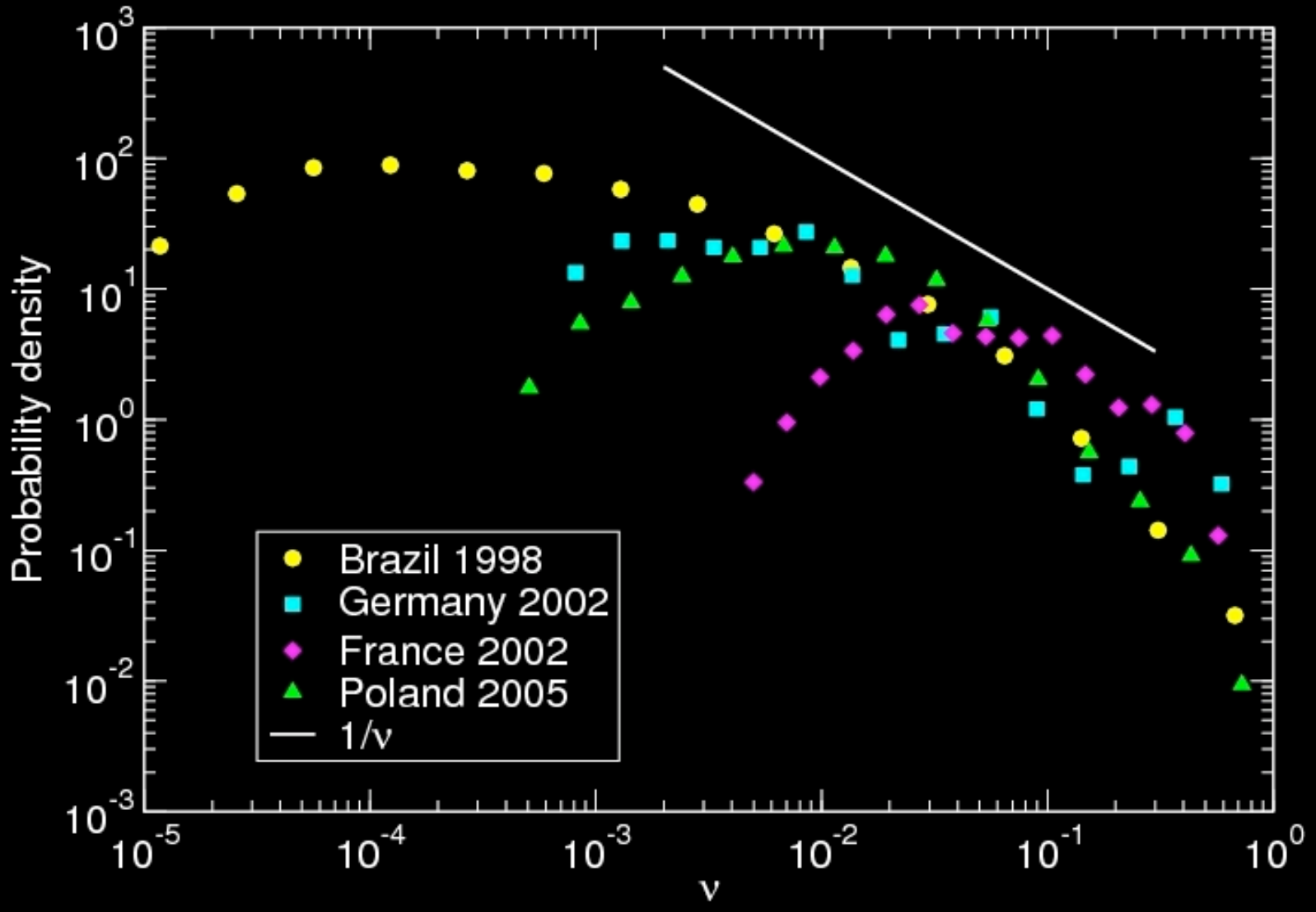


1/v decay reproducible over the years

Indian elections (González et al. IJMPC, 2004)



- 1/v decay occurs in different countries
- Is it universal?



The 1/v behaviour is not universal!

Problem: is it correct to put together candidates of different parties?

Support for different parties wildly fluctuates, in an unpredictable way !

If we model the competition of candidates of the same party, the party does not play any role!

Candidates are chosen based on some form of contact between them and the voters: model!

A new analysis (S.F. & C. Castellano, Phys. Rev. Lett. 99, 138701, 2007)

Proportional elections with open lists

Examples:
Italy (1946-1992), Poland, Finland

Distribution of votes for candidates within a party

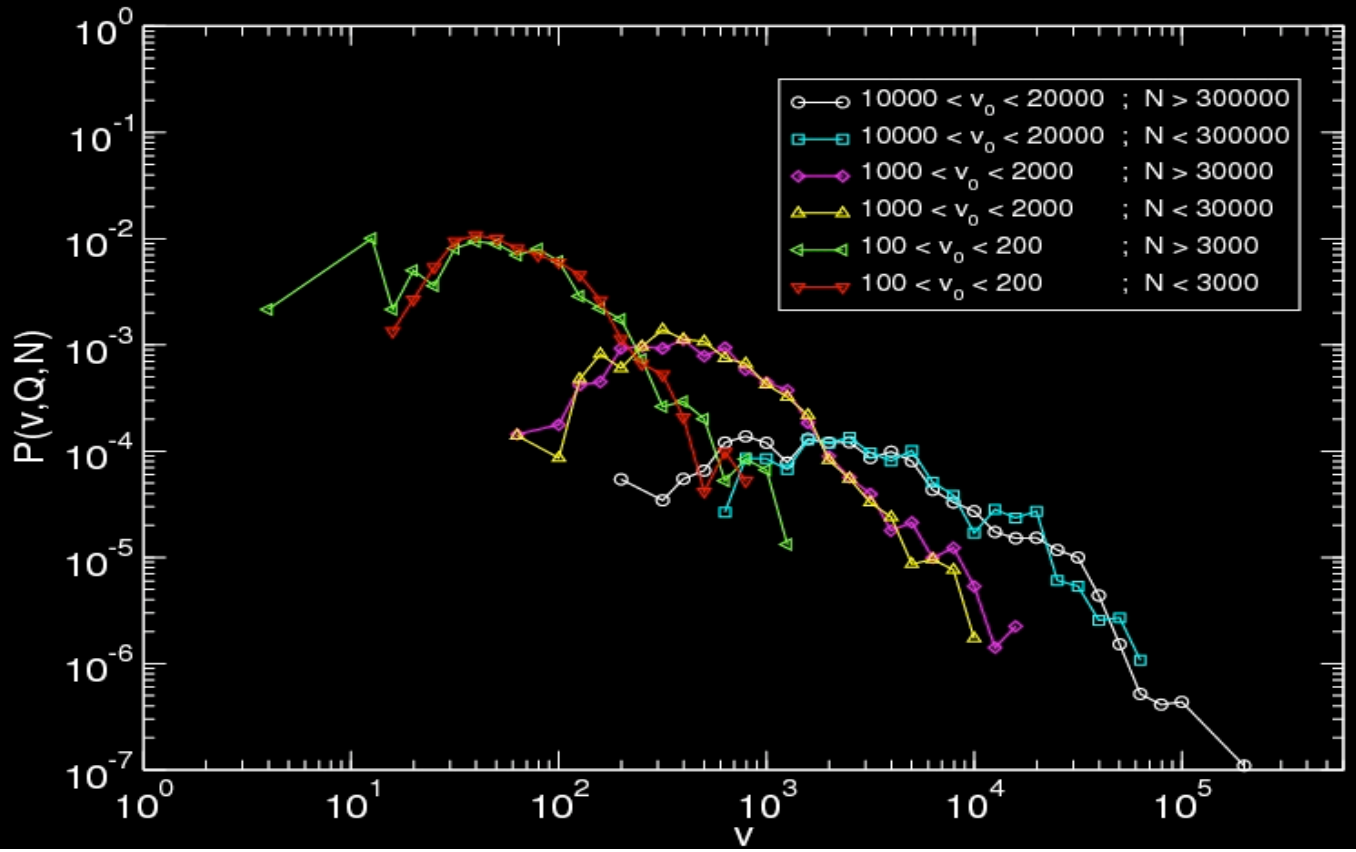
$P(v,Q,N)$

- **N = total votes for party**
- **Q = number of party candidates**

Scaling I

Only two independent variables!

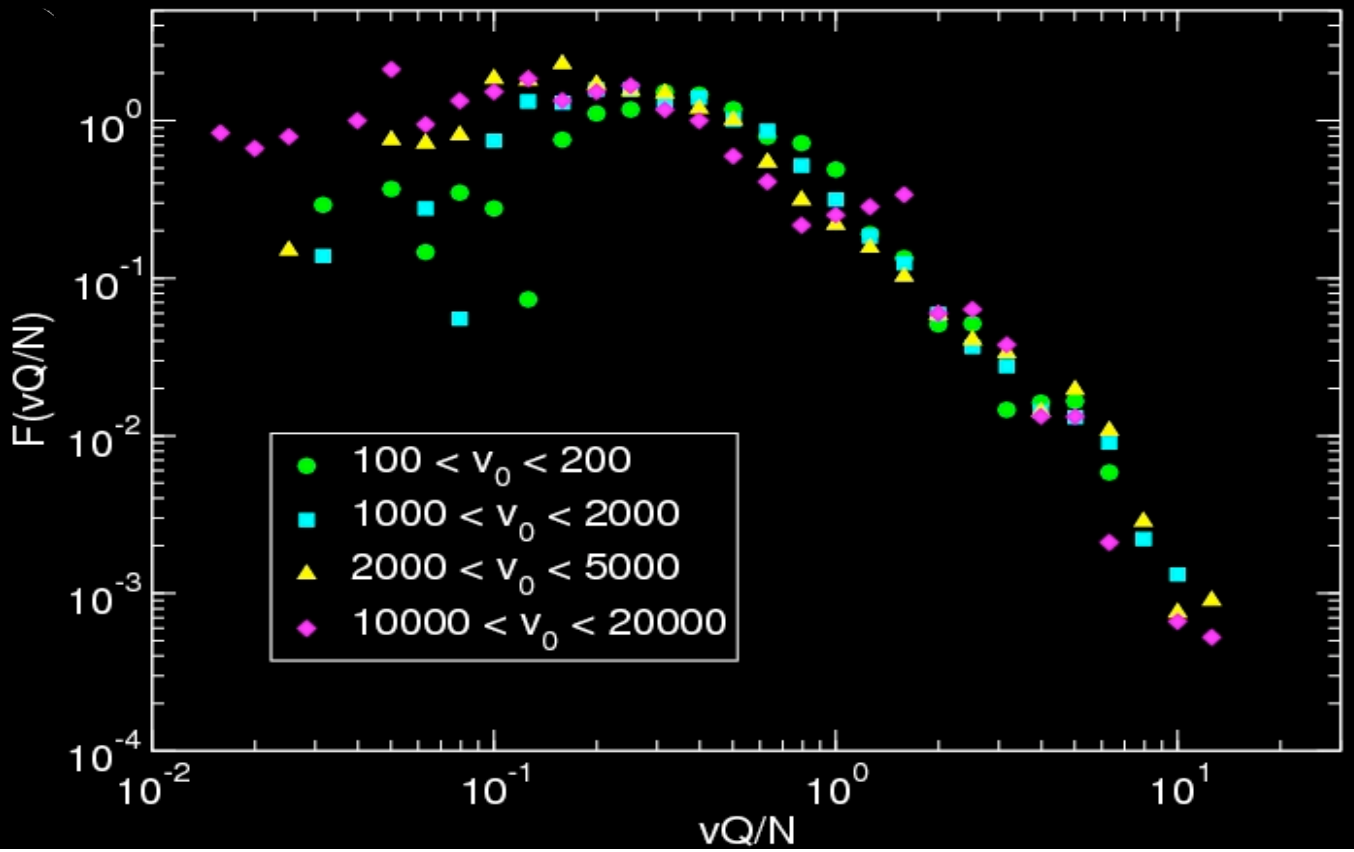
$$P(v,Q,N)=P^{*}(v,N/Q)= P^{*}(v,v_0)$$



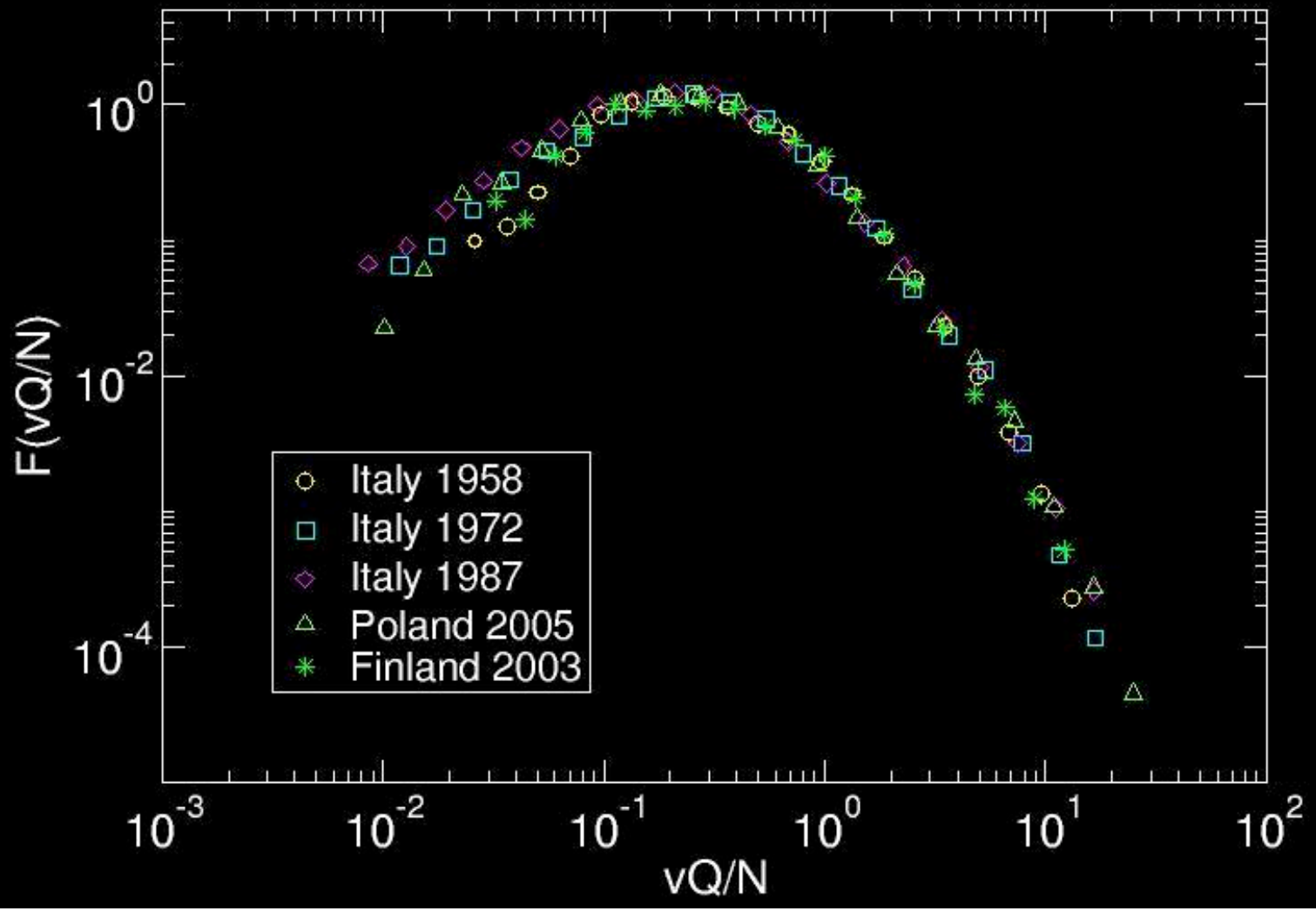
Scaling II

Only one independent variable!

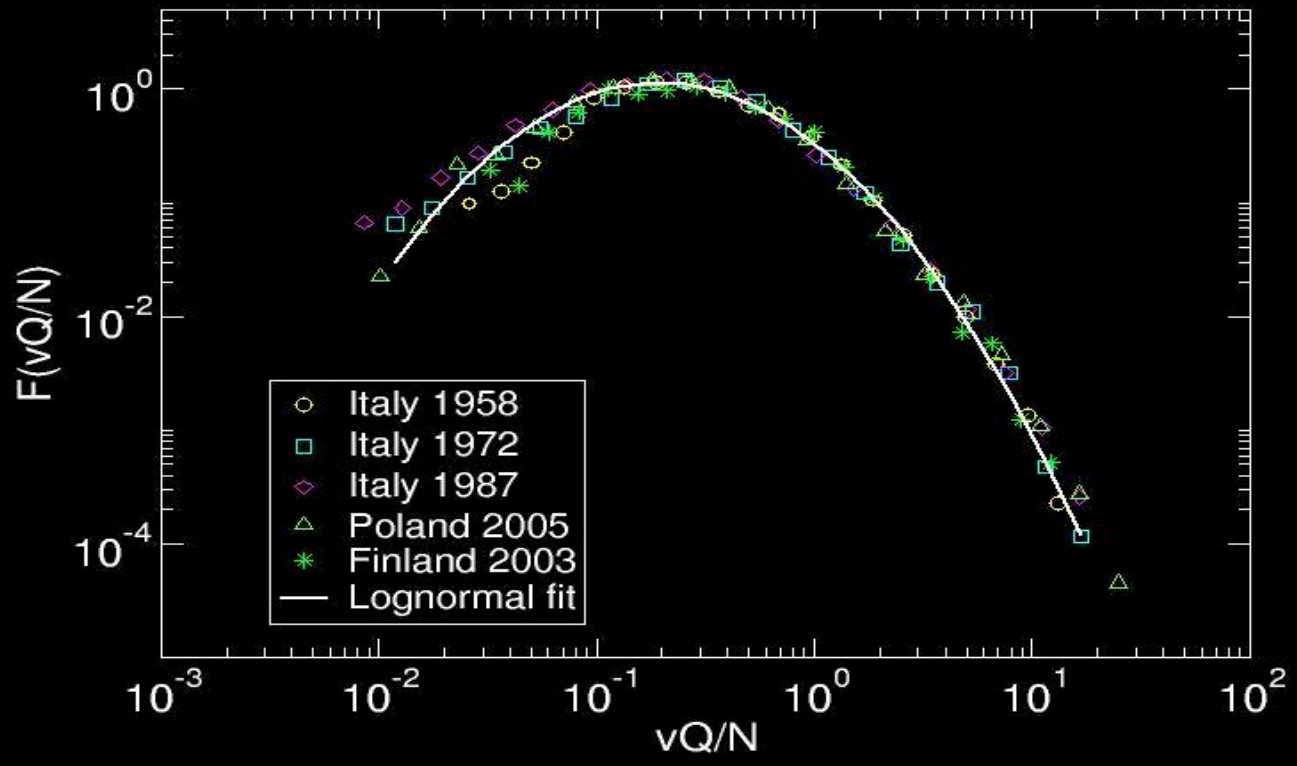
$P(v,Q,N)=P^{*}(v,N/Q)= F(vQ/N)!$



The scaling function is universal!



The universal curve has a lognormal shape!

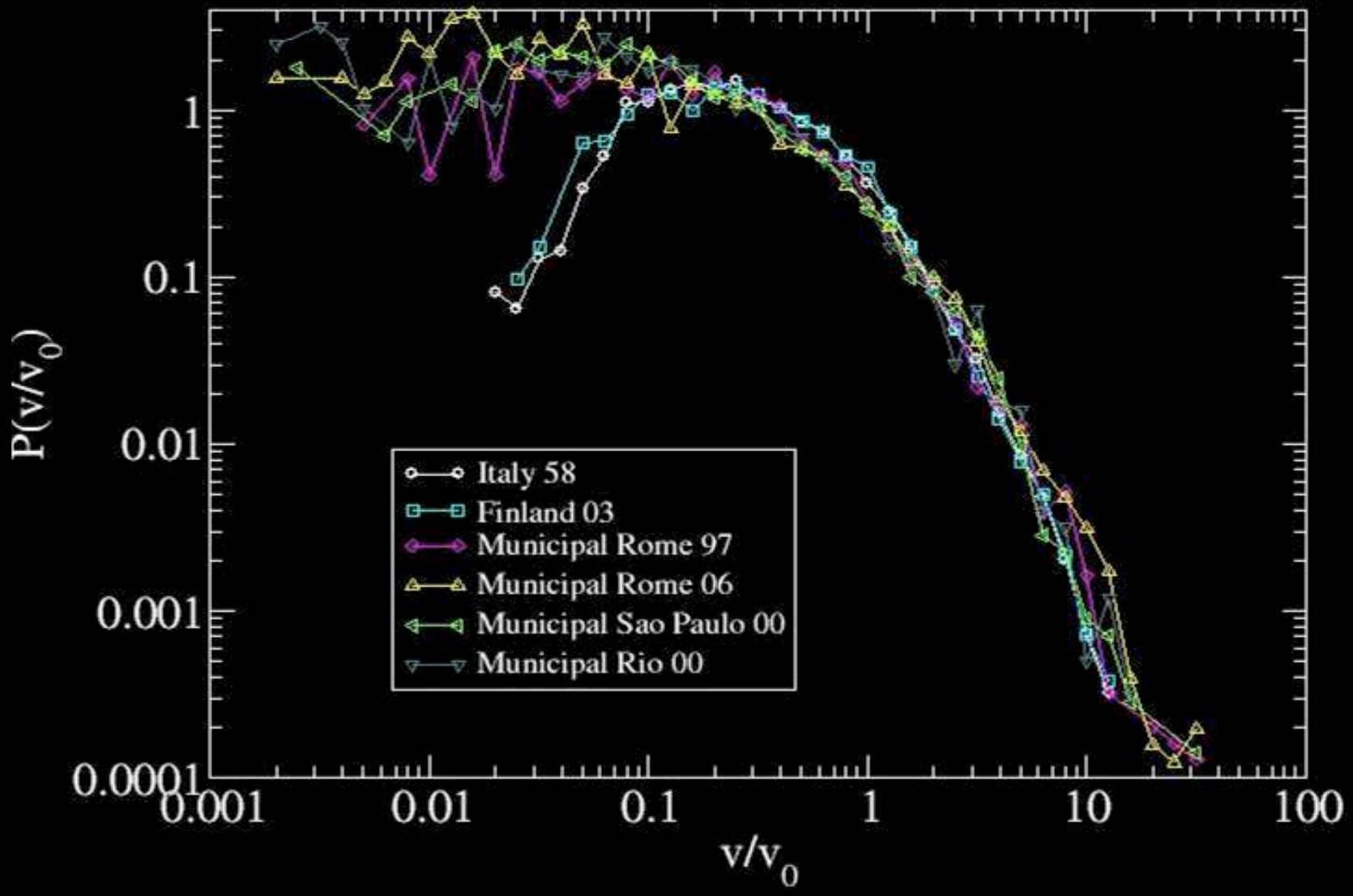


$$F(x) = \frac{1}{\sqrt{2\pi}\,\sigma x} e^{-(\ln(x)-\mu)^2/2\sigma^2}$$

$$\mu = -0.45$$

$$\sigma^2 = 0.91$$

Municipal elections display identical decay



This week

The natural pattern behind our votes

Voting follows the same pattern regardless of country or economics, and it could all be based on networking

MARK BUCHANAN

ARE you swayed by TV and internet voting campaigns? Political parties all over the world certainly think you are, and spend millions on advertising their candidates. Now an analysis of election results over 30 years in different countries shows that, for each political party, voting follows the same pattern, regardless of nationality, culture, history or economics.

The most important factor determining a candidate's success compared with rivals in the same party turns out to be his or her personal ability to connect with the public. In other words, the key factor could be how many friends you've got on Facebook.

"When it comes to voting," says Santo Fortunato of the Institute for Scientific Interchange in Turin, Italy, "people act in the same way regardless of national identity and the economic or political context. Even modern campaign tools like television and the internet have no great effect."

The influence of the candidate's political party and the prevailing economic conditions usually confound attempts to uncover a voting pattern. Fortunato's approach has revealed that there is indeed a pattern, and that social networking can explain it.

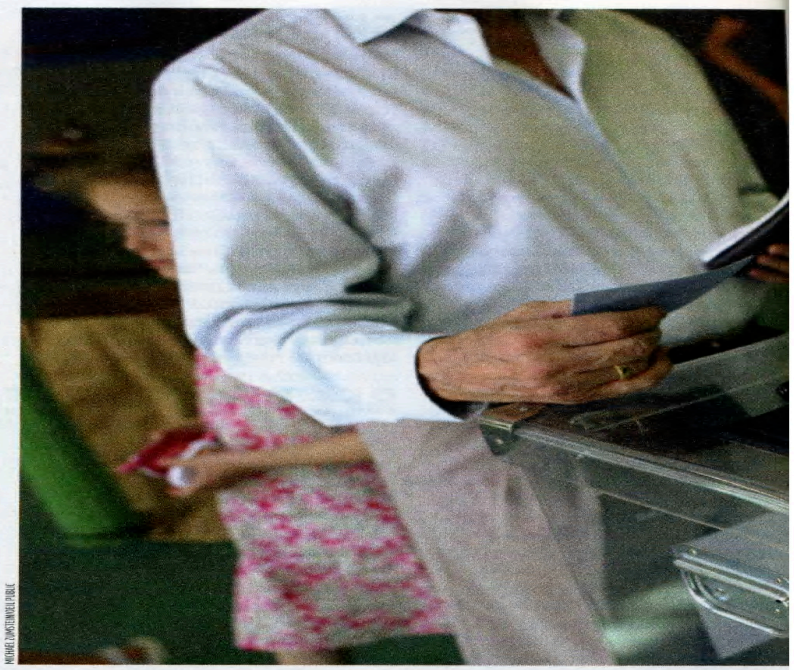
Over the past decade, several independent teams of researchers studying the mathematics of voting behaviour noted an intriguing pattern in election results in countries where elections had many candidates. They found that most candidates received a small number of votes while a few did much better, winning a large fraction of votes.

Looking in detail at elections in Brazil and India, the actual numbers seemed to vary in a regular way: twice as many candidates received 20 per cent as did 40 per cent, twice as many again received 10 per cent as did 20 per cent, and so on. Mathematically, in other words, the number of candidates receiving x per cent of the votes seemed to be simply inversely proportional to x.

However, this didn't seem to be the case in other countries with different election systems, says Fortunato. Working with physicist Claudio Castellano of the University of Rome, Fortunato looked at data from elections in Germany, France, Italy and Poland, and found that there appeared to be no pattern across nations or political systems to the numbers of votes received by each candidate, as one might well expect. On closer examination, though, they found that the differences between nations do not seem to be down to political or cultural differences, but instead reflect the differing influence of political parties within each nation. Controlling for this, they have discovered that how votes get divided between candidates really does follow a universal pattern that seems to be unaffected by political systems, culture or economic conditions.

Voters, they say, can be drawn to vote for a candidate for two main reasons. First, there's the intrinsic appeal of a candidate, based on their personality and character, their articulated positions and ability to connect with the voters. Then there's the influence of political parties, which attract voters to a broad philosophy or set of policies. The distribution of votes between candidates depends on both factors, and so doesn't reflect a candidate's personal attraction alone.

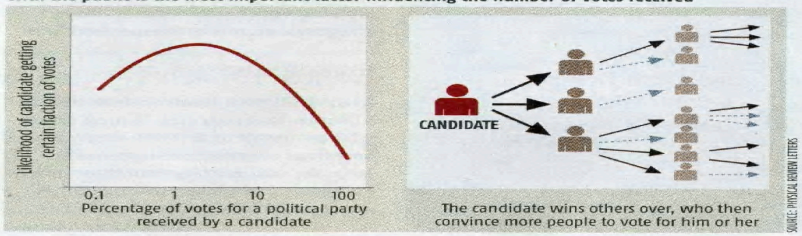
Fortunato and Castellano suspected that there might be a voting pattern hidden by this mingling of influences that held across nations. To test the idea they looked for data from



MICHAEL LONGHURST/PUBLIC

A UNIVERSAL PATTERN OF VOTING

When the influence of political parties is removed, a candidate's personal ability to connect with the public is the most important factor influencing the number of votes received



SOURCE: PHYSICAL REVIEW LETTERS

Citations

References

1. Zárský V, Cvrèková F: **Small GTPases in the morphogenesis of yeast and plant cells**. In *Molecular Mechanisms of Signalling and Membrane Transport*. Edited by Wirtz KW. Berlin: Springer, 1997, 75-88.
2. Sanderfoot AA, Raikhel N: **The specificity of vesicle trafficking: coat proteins and SNAREs**. *Plant Cell*, 1999, **11**:629-642.
3. Li H, Wu G, Ware D, Davis KR, Yang Z: **Arabidopsis Rho-related GTPases: differential gene expression in pollen and polar localization in fission yeast**. *Plant Physiol*, 1998, **118**:407-417.
4. Field C, Oegema K: **Cytokinesis in eukaryotes: a mechanic comparison**. *Curr Opin Cell Biol*, 1999, **11**:68-90.
5. Evangelista M, Blundell K, Longtine MS, Chow CJ, Adames N, Pringle R, Peter M, Boone C: **Bnilp, a yeast formin linking Cdc42p and the actin cytoskeleton during polarized morphogeneis**. *Science*, 1997, **276**:118-122.
6. Zeller R, Haramis AG, Zuniga A, McGuigan C, Dono R, Davidson G, Chabanis S, Gibson T: **Formin defines a large family of morphoregulatory genes and functions in establishment of the polarizing region**. *Cell Tissue Res*, 1999, **296**:85-93.
7. Heil-Chapelaine R, Adames N, Cooper JA: **Formin' the connection between microtubules and the cell cortex**. *J Cell Biol*, 1999, **144**:809-811.
8. Frazier J, Field C: **Actin cytoskeleton: are FH proteins local organizers?**. *Curr Biol*, 1997, **7**:R414-R417.

Lots of data from various sources

Description of the dataset

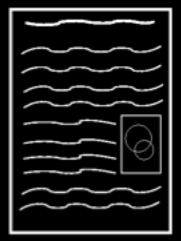
ISI Web of Knowledge℠

Subject Categories

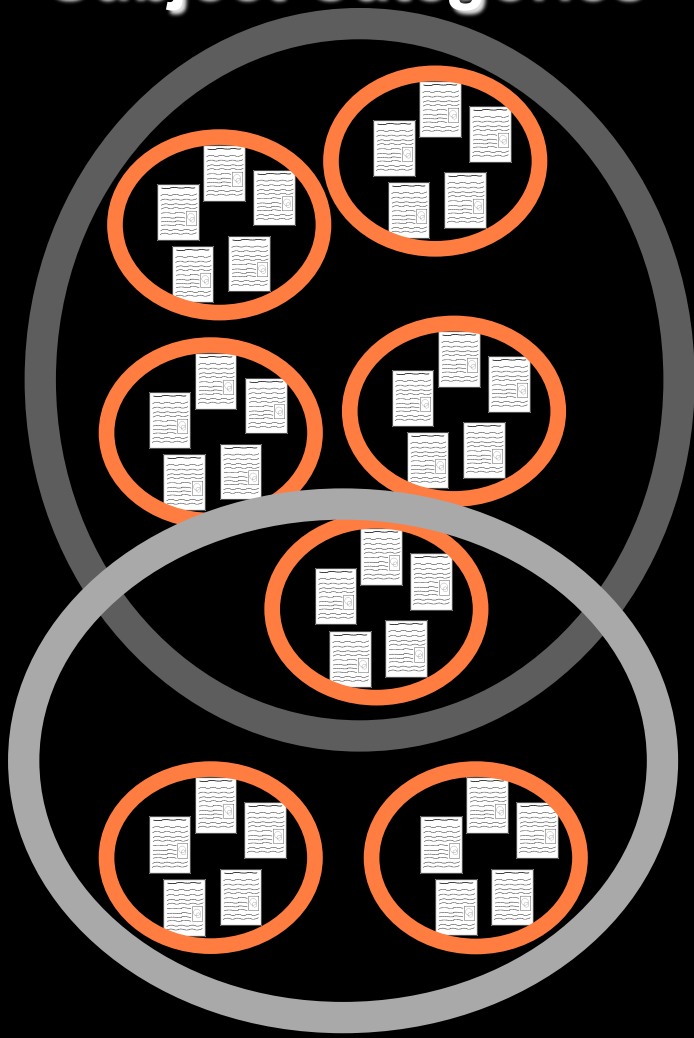
Journals

Papers

Publication year



Number of citations



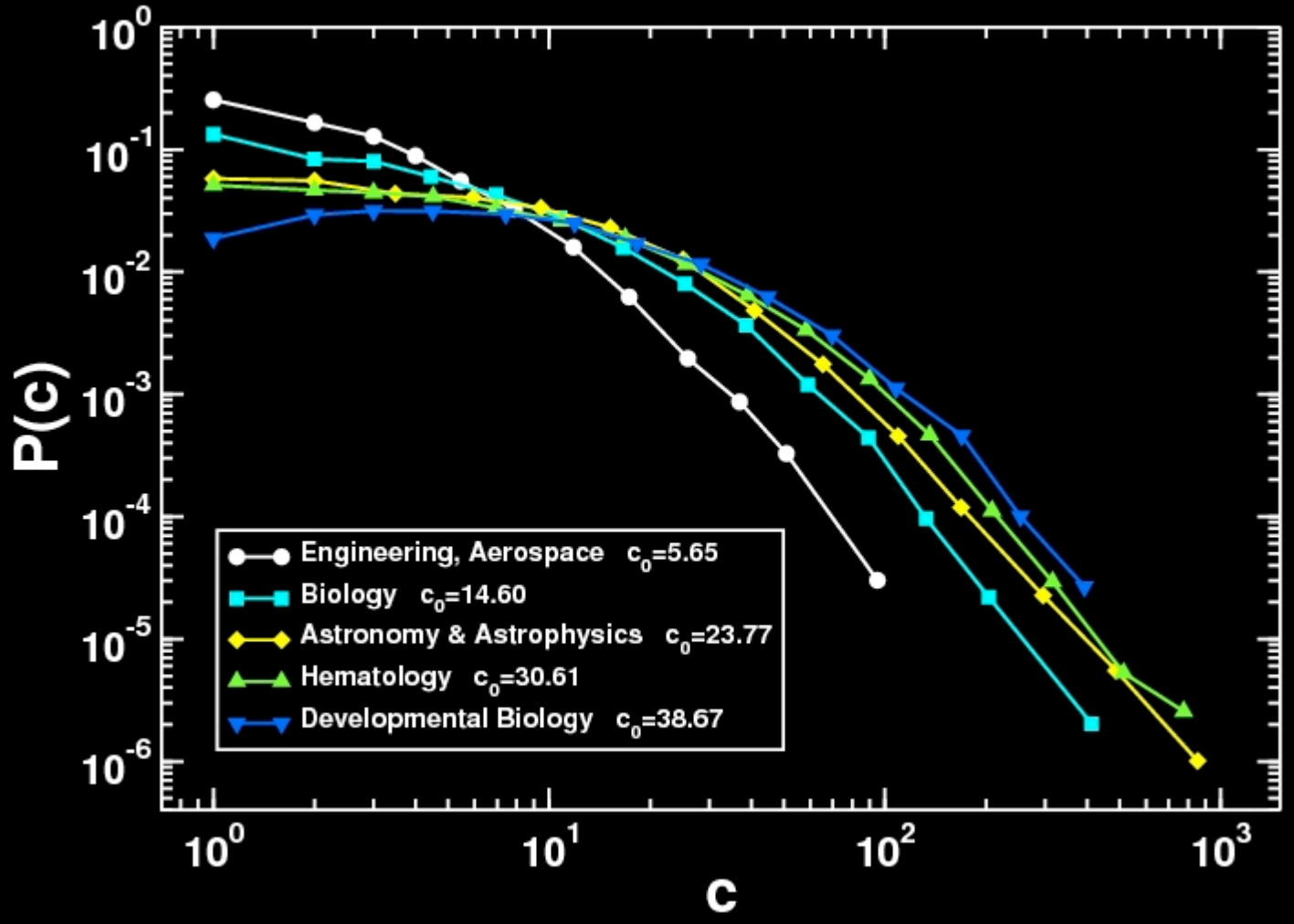
Papers are classified in 172 scientific disciplines (from *Acoustics* to *Zoology*)

Different scientific disciplines

Index	Subject category	Year	N_p	c_0	c_{max}	σ^2	χ^2/df
1	Agricultural economics and policy	1999	266	6.88	42	1.0 (1)	0.007
2	Allergy	1999	1,530	17.39	271	1.4 (2)	0.012
3	Anesthesiology	1999	3,472	13.25	282	1.8 (2)	0.009
4	Astronomy and astrophysics	1999	7,399	23.77	1,028	1.1 (1)	0.003
5	Biology	1999	3,400	14.6	413	1.3 (1)	0.004
6	Computer science, cybernetics	1999	704	8.49	100	1.3 (1)	0.004
7	Developmental biology	1999	2,982	38.67	520	1.3 (3)	0.002
8	Engineering, aerospace	1999	1,070	5.65	95	1.4 (1)	0.003
9	Hematology	1990	4,423	41.05	1,424	1.5 (1)	0.002
10	Hematology	1999	6,920	30.61	966	1.3 (1)	0.004
11	Hematology	2004	8,695	15.66	1,014	1.3 (1)	0.003
12	Mathematics	1999	8,440	5.97	191	1.3 (4)	0.001
13	Microbiology	1999	9,761	21.54	803	1.0 (1)	0.005
14	Neuroimaging	1990	444	25.26	518	1.1 (1)	0.004
15	Neuroimaging	1999	1,073	23.16	463	1.4 (1)	0.003
16	Neuroimaging	2004	1,395	12.68	132	1.1 (1)	0.005
17	Physics, nuclear	1990	3,670	13.75	387	1.4 (1)	0.001
18	Physics, nuclear	1999	3,965	10.92	434	1.4 (4)	0.001
19	Physics, nuclear	2004	4,164	6.94	218	1.4 (1)	0.001
20	Tropical medicine	1999	1,038	12.35	126	1.1 (1)	0.017

Source of data ISI Web of Knowledge℠

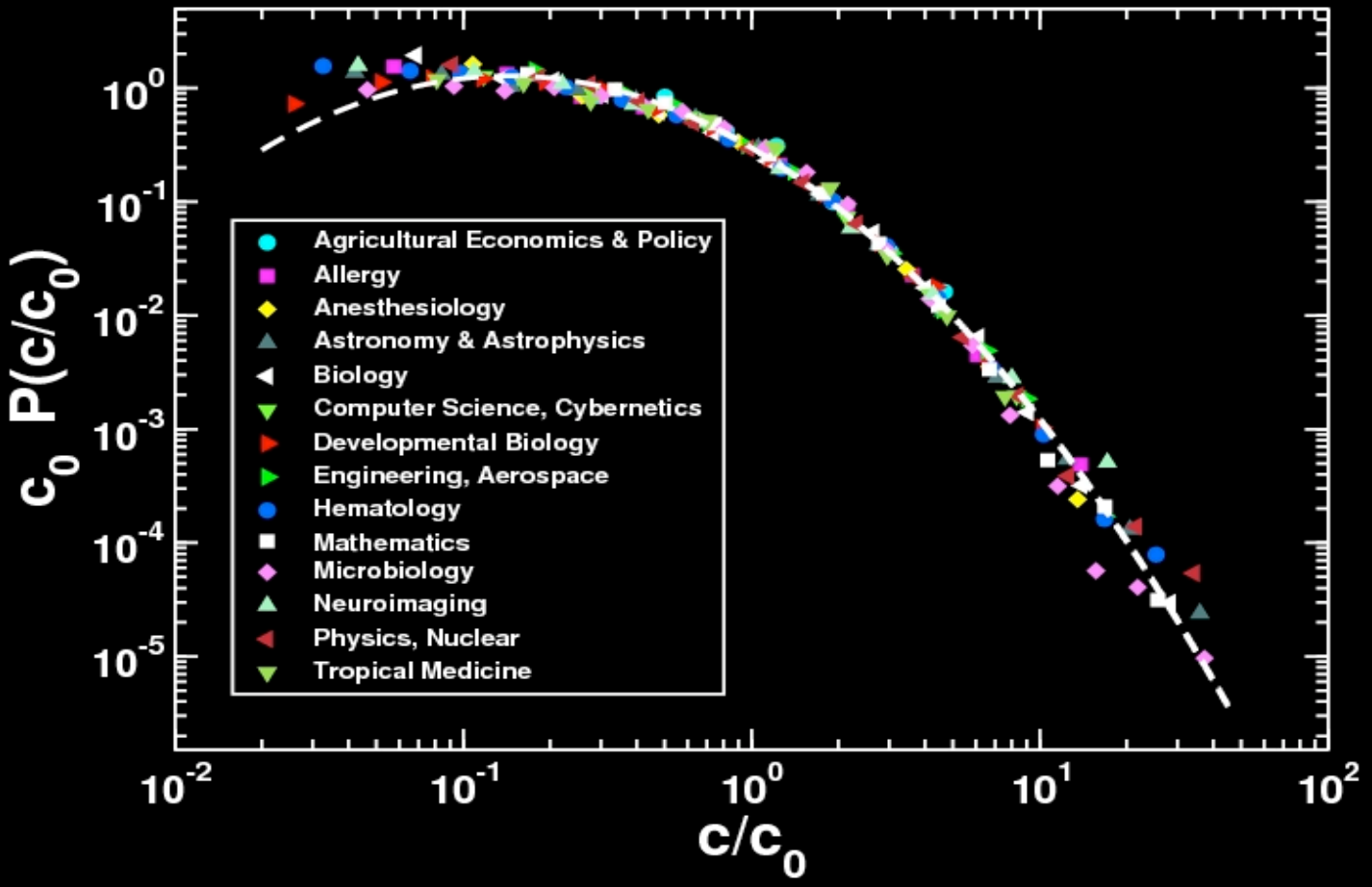
Distribution of cites?



Dependence on field (ISI category)!

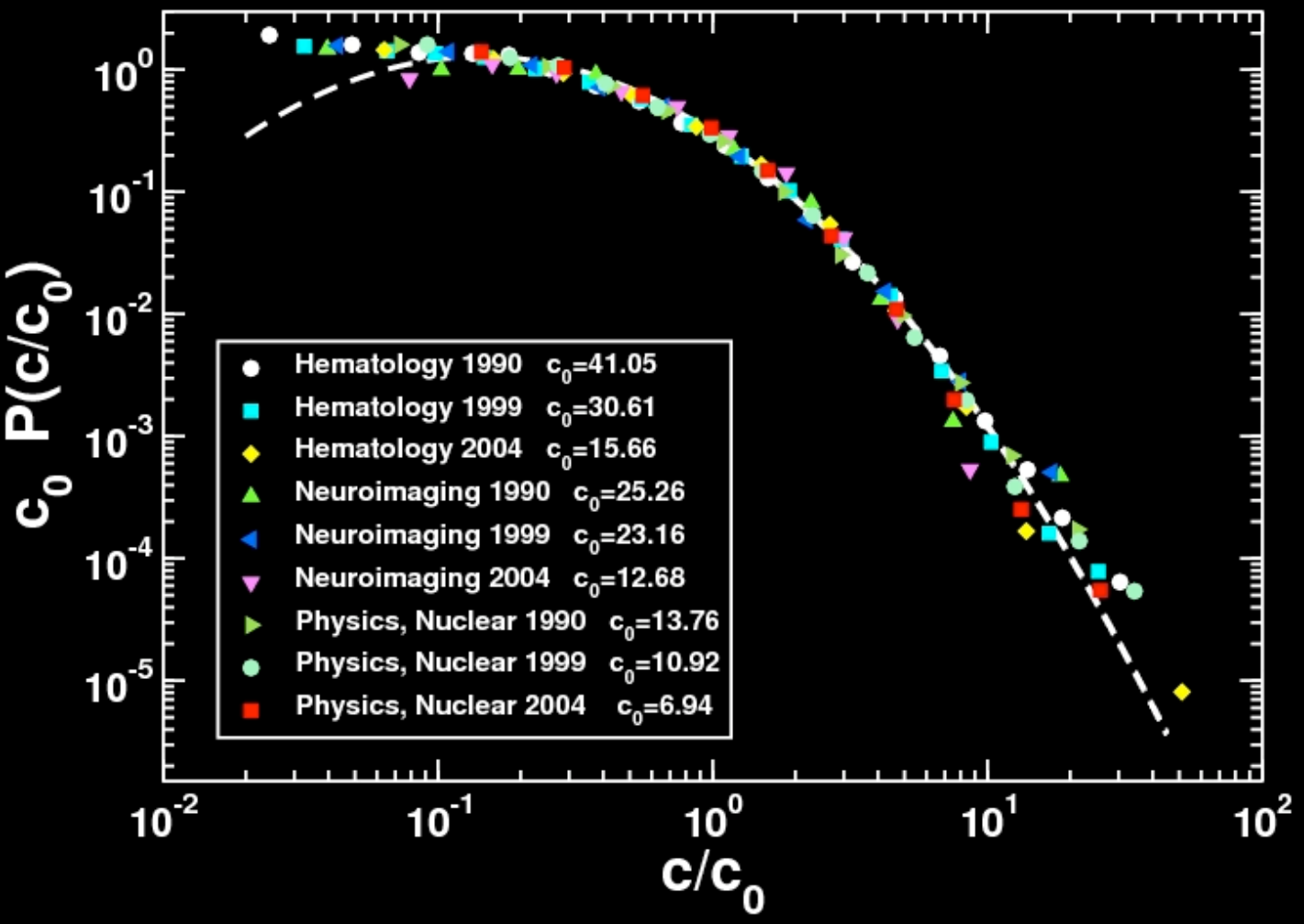
The average number of citations per paper c_0 varies a lot with the field

Could c_0 be the reason of the discrepancy?



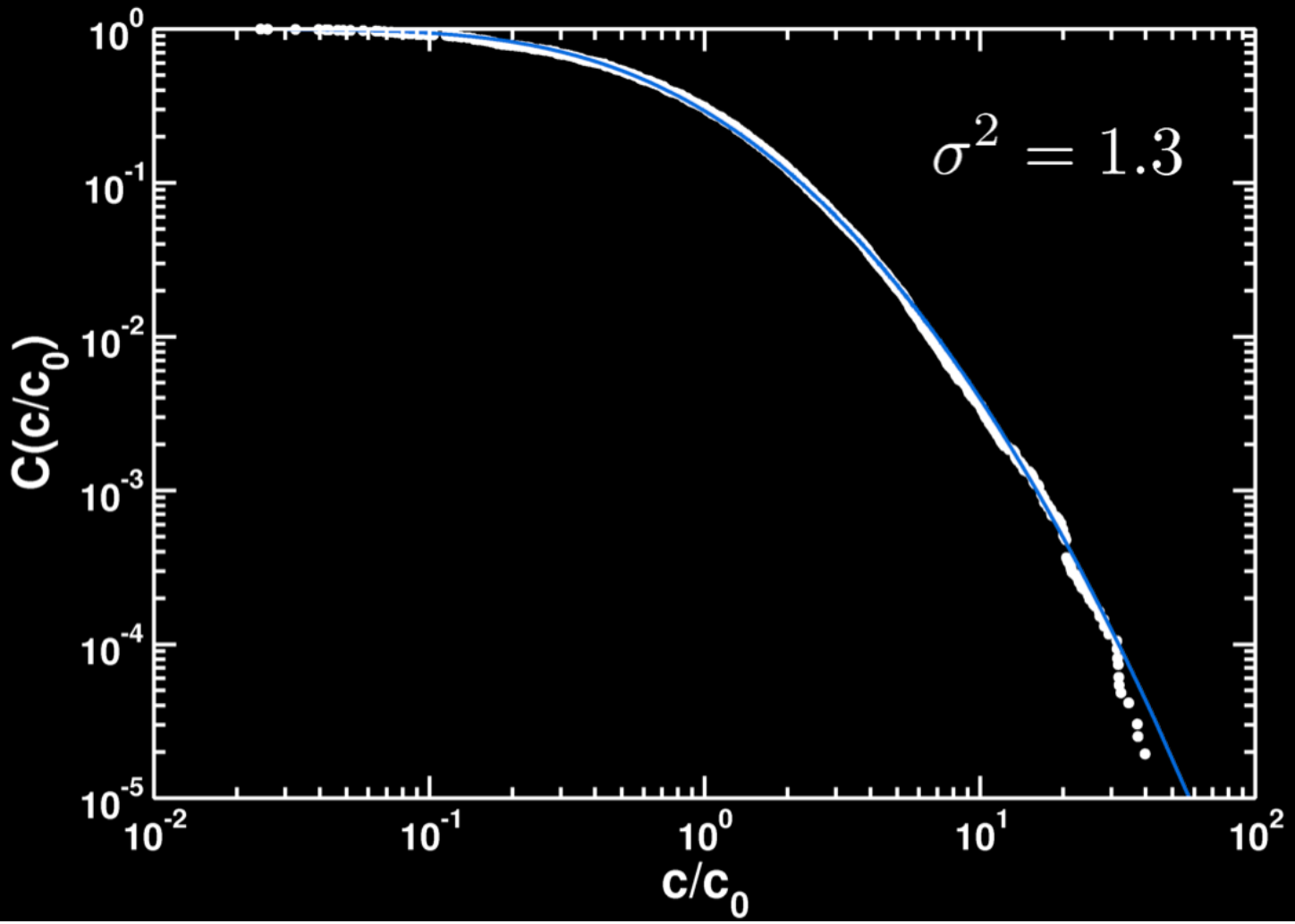
F. Radicchi, S.F. and C. Castellano,
Proc. Natl. Acad. Sci. USA 105, 17268 (2008)

The universal distribution is stable in time!



Fitting the universal function

$$Q(x) = \frac{1}{\sqrt{2\pi}\, x\, \sigma} \exp\left\{ -\frac{\left[\ln(x) + \sigma^2/2\right]^2}{2\,\sigma^2} \right\},\ x = c/c_0$$

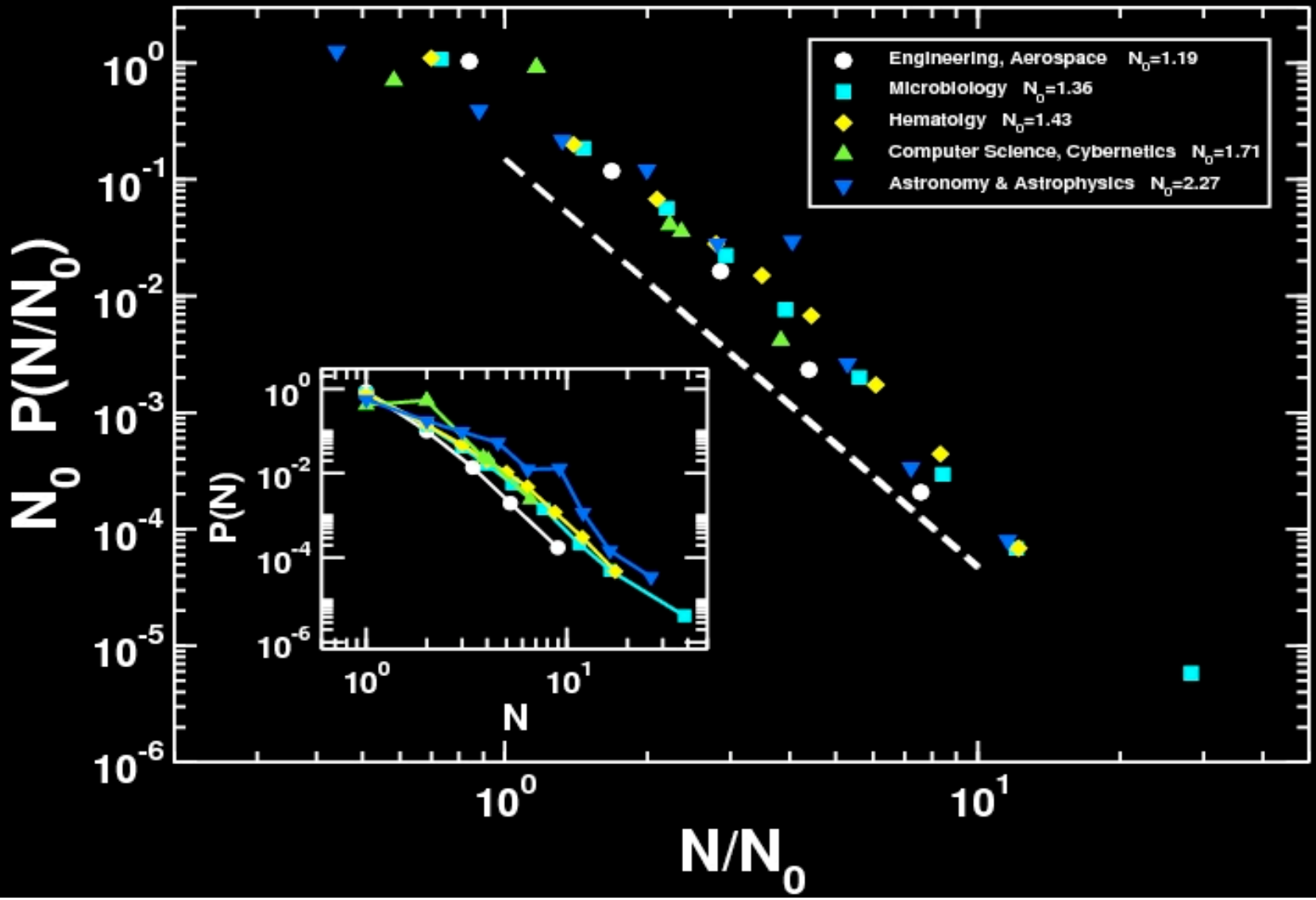


Different scientific disciplines

Index	Subject category	Year	N_p	c_0	c_{max}	σ^2	χ^2/df
1	Agricultural economics and policy	1999	266	6.88	42	1.0 (1)	0.007
2	Allergy	1999	1,530	17.39	271	1.4 (2)	0.012
3	Anesthesiology	1999	3,472	13.25	282	1.8 (2)	0.009
4	Astronomy and astrophysics	1999	7,399	23.77	1,028	1.1 (1)	0.003
5	Biology	1999	3,400	14.6	413	1.3 (1)	0.004
6	Computer science, cybernetics	1999	704	8.49	100	1.3 (1)	0.004
7	Developmental biology	1999	2,982	38.67	520	1.3 (3)	0.002
8	Engineering, aerospace	1999	1,070	5.65	95	1.4 (1)	0.003
9	Hematology	1990	4,423	41.05	1,424	1.5 (1)	0.002
10	Hematology	1999	6,920	30.61	966	1.3 (1)	0.004
11	Hematology	2004	8,695	15.66	1,014	1.3 (1)	0.003
12	Mathematics	1999	8,440	5.97	191	1.3 (4)	0.001
13	Microbiology	1999	9,761	21.54	803	1.0 (1)	0.005
14	Neuroimaging	1990	444	25.26	518	1.1 (1)	0.004
15	Neuroimaging	1999	1,073	23.16	463	1.4 (1)	0.003
16	Neuroimaging	2004	1,395	12.68	132	1.1 (1)	0.005
17	Physics, nuclear	1990	3,670	13.75	387	1.4 (1)	0.001
18	Physics, nuclear	1999	3,965	10.92	434	1.4 (4)	0.001
19	Physics, nuclear	2004	4,164	6.94	218	1.4 (1)	0.001
20	Tropical medicine	1999	1,038	12.35	126	1.1 (1)	0.017

Source of data ISI Web of Knowledge℠

Another regularity: scientific productivity!



Other evidence?

- Elections
- Consumer behavior
- Financial behavior
- Web user behavior
- Web-based experiments

Information not only from stationary states, but also from dynamics

Ex. “Collective opinion shifts”, Michard & Bouchaud, EPJB (2005)

Outlook

- The distribution of the number of votes received by candidates of the same party in proportional elections is universal!
- The distribution of the number of citations of papers in the same discipline, normalized by the average citation score, is universal!
- Search for other regularities in data is necessary to create a quantitative phenomenology in social dynamics

REVIEWS OF MODERN PHYSICS, VOLUME 81, APRIL–JUNE 2009

Statistical physics of social dynamics

Claudio Castellano*

SMC, INFM-CNR and Dipartimento di Fisica, "Sapienza" Università di Roma, Piazzale A. Moro 2, 00185 Roma, Italy

Santo Fortunato†

Complex Networks Lagrange Laboratory, ISI Foundation, Viale S. Severo 65, 10133 Torino, Italy

Vittorio Loreto‡

Dipartimento di Fisica, "Sapienza" Università di Roma and SMC, INFM-CNR, Piazzale A. Moro 2, 00185 Roma, Italy and Complex Networks Lagrange Laboratory, ISI Foundation, Viale S. Severo 65, 10133 Torino, Italy

(Published 11 May 2009)

Statistical physics has proven to be a fruitful framework to describe phenomena outside the realm of traditional physics. Recent years have witnessed an attempt by physicists to study collective phenomena emerging from the interactions of individuals as elementary units in social structures. A wide list of topics are reviewed ranging from opinion and cultural and language dynamics to crowd behavior, hierarchy formation, human dynamics, and social spreading. The connections between these problems and other, more traditional, topics of statistical physics are highlighted. Comparison of model results with empirical data from social systems are also emphasized.

DOI: 10.1103/RevModPhys.81.591 PACS number(s): 05.10.−a, 89.20.−a, 89.75.−k

CONTENTS

*Electronic address: claudio.castellano@roma1.infn.it
†Electronic address: fortunato@isi.it
‡Electronic address: vittorio.loreto@roma1.infn.it

C. Castellano, S. F., V. Loreto, Rev. Mod. Phys. 81, 591 (2009)