HOME ABOUT CONSTANTINO REGISTRATION PROGRAMME IMPORTANT DATES PARTICIPANTS SPECIAL ISSUE ADDITIONAL INFORMATION

MY TALK

STATISTICAL MECHANICS FOR COMPLEXITY

A CELEBRATION OF THE 80TH BIRTHDAY OF CONSTANTINO TSALLIS

RIO DE JANEIRO, 6 TO 10 NOVEMBER 2023

1st part

about PHYSICS

2nd part

about HISTORY

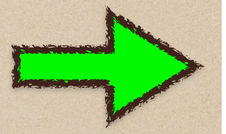
Signature of Nonextensive Statistical Mechanics in Asymptotically Scale-free Random Networks

Ugur TIRNAKLI
İzmir University of Economics
Physics Department, İzmir-Turkey

Conference "Statistical Mechanics for Complexity – A Celebration of the 80th Birthday of C. Tsallis", Rio de Janeiro, Brazil, 6/11/2023

EPISODE 1

The story begins with this



EUROPHYSICS LETTERS 1 April 2005

Europhys. Lett., **70** (1), pp. 70–76 (2005)
DOI: 10.1209/epl/i2004-10467-y

Preferential attachment growth model and nonextensive statistical mechanics

D. J. B. Soares[1,2], C. Tsallis[3,4], A. M. Mariz[1] and L. R. da Silva[1]

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Campus Universitario, 59072-970 Natal-RN, Brazil
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60451-970, Fortaleza-Ce, Brazil
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22290-180 Rio de Janeiro-RJ, Brazil
[4] *Santa Fe Institute - 1399 Hyde Park Road, Santa Fe, NM 87501, USA*

Aim: to explore the connection between scale-free networks and q-statistics.

Method: to propose growth models to explore this connection.

GROWTH MODEL

- Construct a single connected network of sites (or nodes or vertices) and links (or bonds or edges) by gradually (sequentially) making it grow.

- First fix one site ($i = 1$) at some arbitrary origin of the plane.

- Second site ($i = 2$) is randomly and isotropically chosen at a distance r distributed according to the probability law

$$P_G(r) \propto \frac{1}{r^{2+\alpha_G}}$$

- This second site is then linked to the first one.

GROWTH MODEL

- Now locate the new origin as the barycenter of the two first sites.
- Apply again the distribution $P_G(r)$ from this new origin and locate the third site ($i = 3$).
- This third site is now going to be linked to only one of the pre-existing two sites.

?? HOW ??

GROWTH MODEL

To do this, use an attachment probability

$$p_A \propto \frac{k_i}{r_{ij}^{\alpha_G}} \qquad (\alpha_A \geq 0)$$

where r_{ij} is the distance of the newly arrived site to the i^{th} site of the pre-existing cluster.

k_i is the connectivity defined as the number of links already arriving to the same site (at the present stage, $k_1 = k_2 = 1$).

GROWTH MODEL

- This process is sequentially repeated as many as we like.

If N is the total number of sites of the cluster, then the linking of the newly arrived site ($i = N$) is done with the probability

$$p_A = \frac{k_i \, r_{ij}^{-\alpha_A}}{\sum_{j=1}^{N-1} k_j \, r_{ij}^{-\alpha_A}}$$

The dynamics of the model makes the arriving sites to have preferential attachment to the previous sites that already have many links (hubs), as long as they are not too far.

GROWTH MODEL

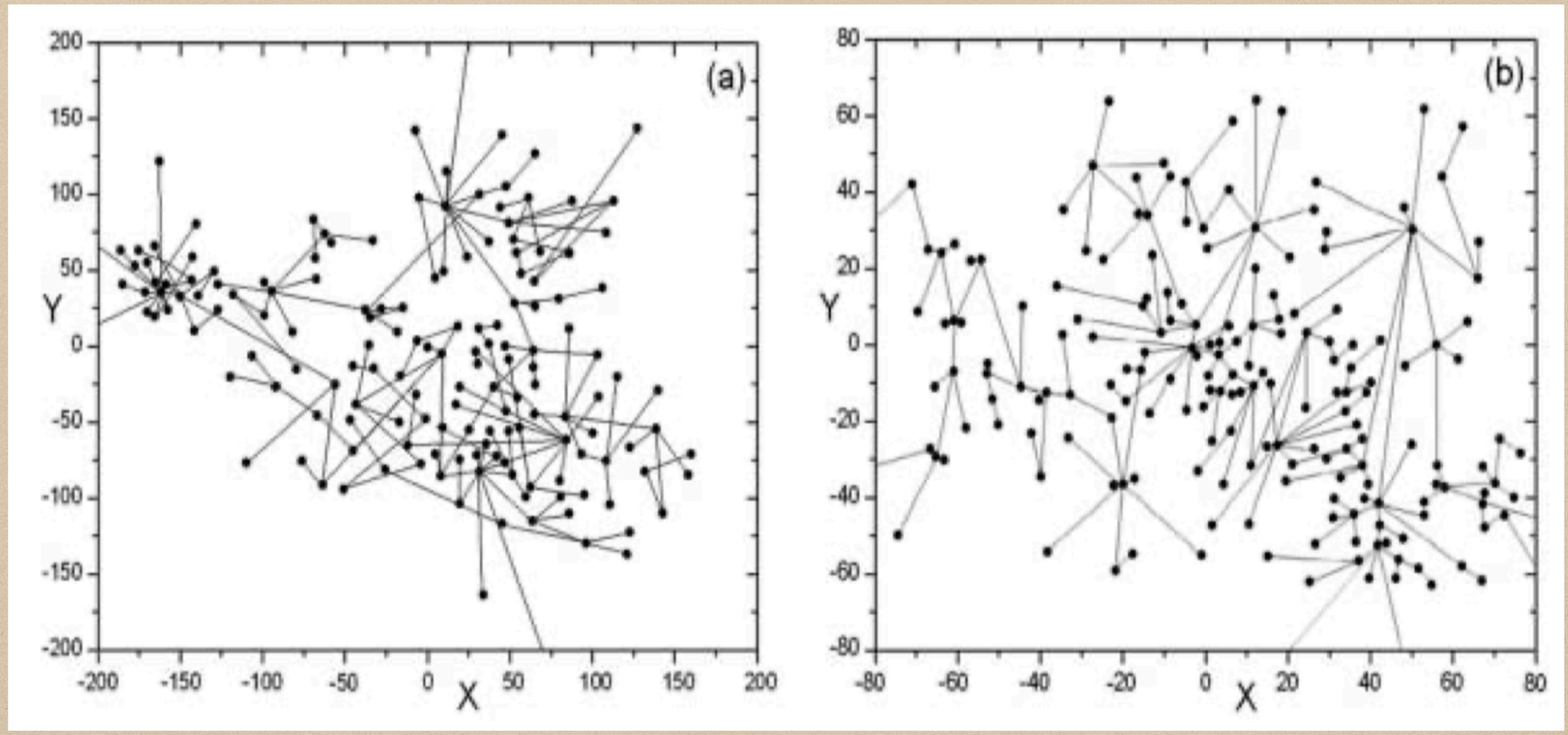
$$p_A = \frac{k_i \, r_{ij}^{-\alpha_A}}{\sum_{j=1}^{N-1} k_j \, r_{ij}^{-\alpha_A}}$$

This competition between connectivity and Euclidean proximity is <u>less pronounced</u> when α_A is close to zero

and <u>completely disappears</u> only at $\alpha_A = 0$.

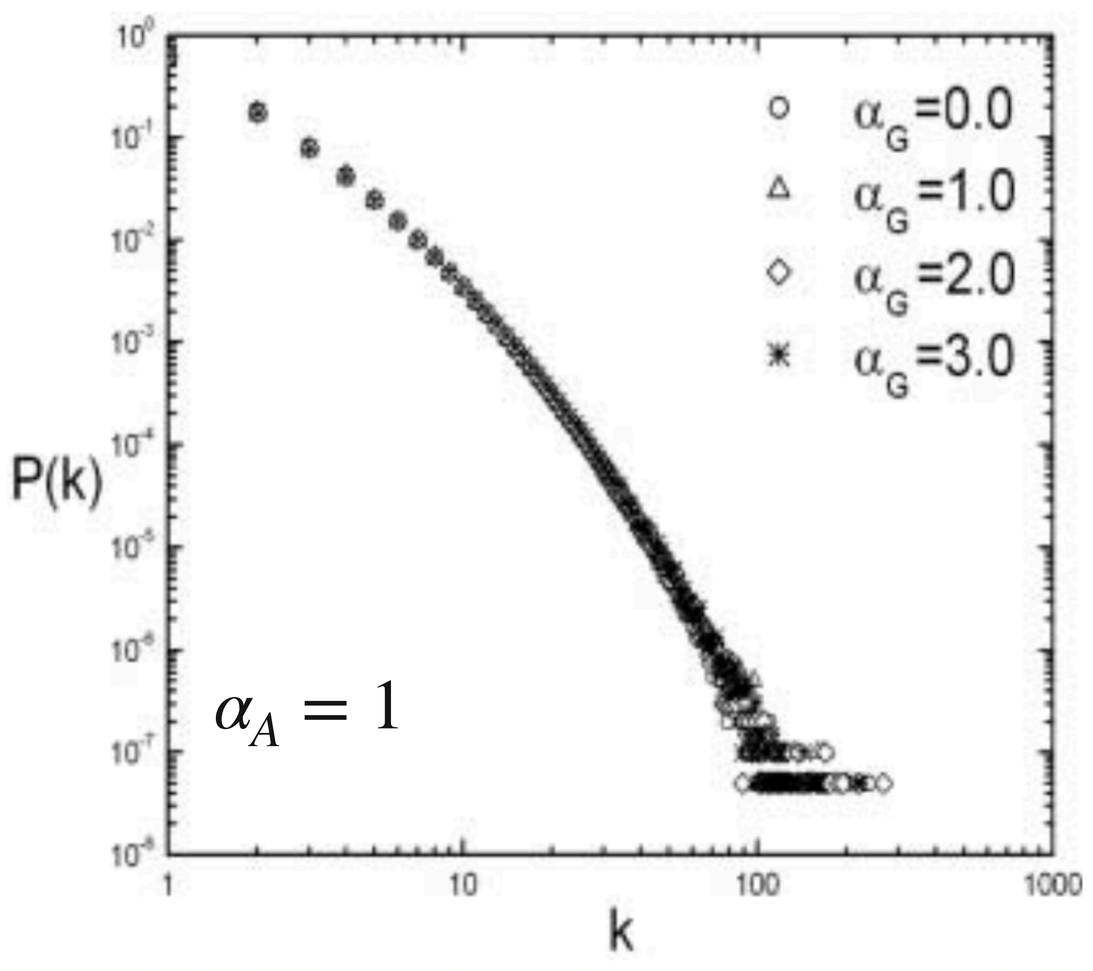
For this particular case, one expects behavior consistent with the Barabasi-Albert model, which has topology but no metrics.

Typical networks obtained from the model



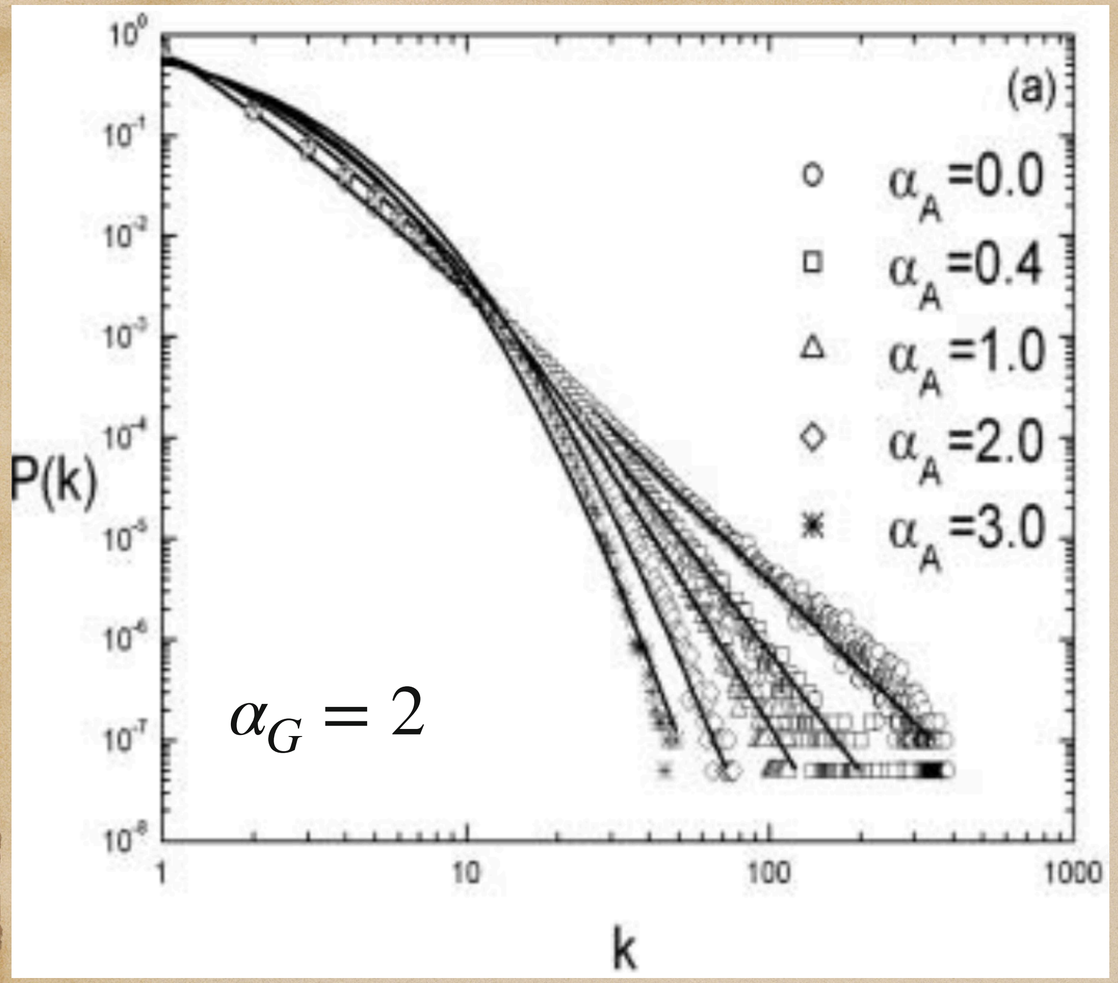
$(\alpha_G, \alpha_A) = (1,0)$ $(\alpha_G, \alpha_A) = (1,4)$

Soares et al., EPL 70 (2005) 70.



Parameter α_G controls the metrics but has no influence on the connectivity distribution.

Soares et al., EPL 70 (2005) 70.



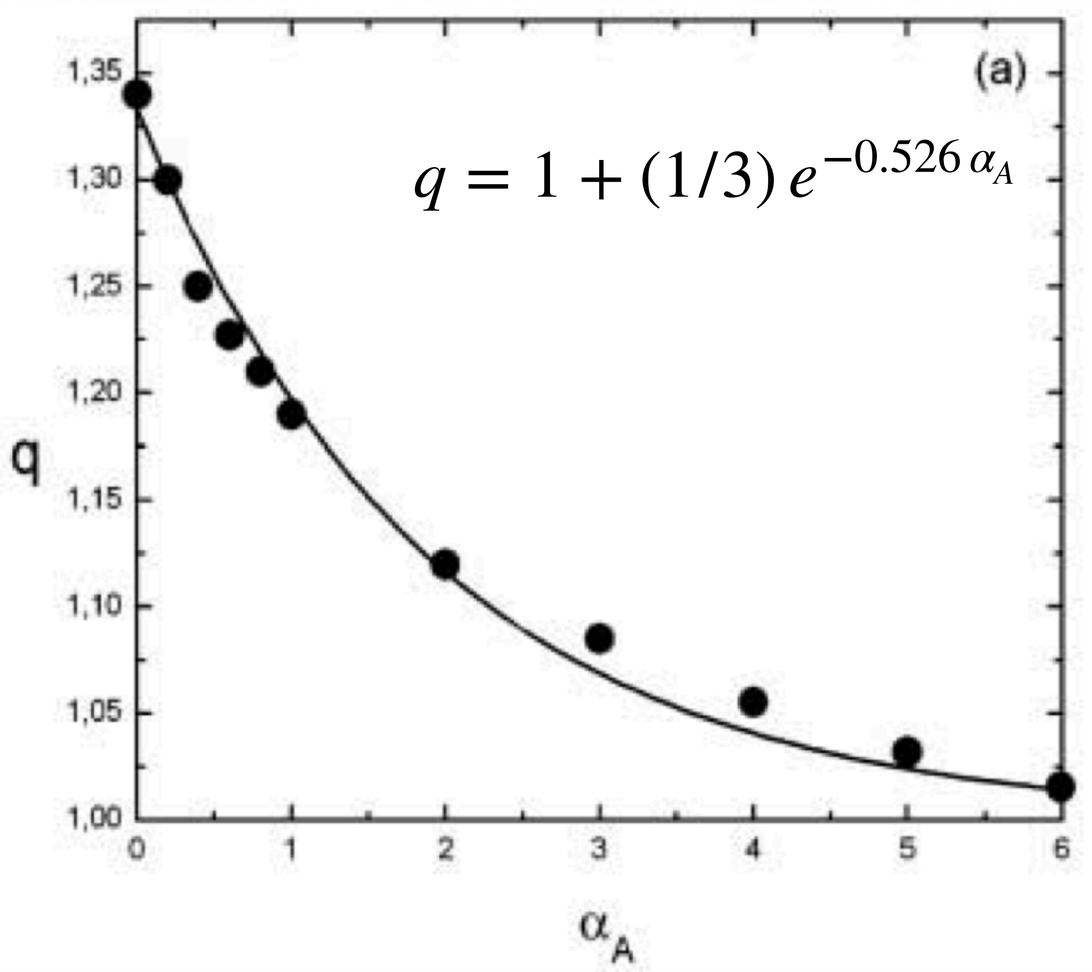
On the other hand, parameter α_A has a big influence on the connectivity distribution.

Try q-exponentials to fit the results.!!

$$P(k) = P(0)\, e_q^{-k/\kappa}$$

$$e_q^x = \left[1 + (1-q)x\right]^{1/(1-q)} \qquad (e_1^x = e^x)$$

Soares et al., EPL 70 (2005) 70.



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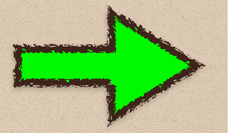
Soares et al., EPL 70 (2005) 70.

EPISODE 2

Then comes the role of dimension



www.nature.com/scientificreports

SCIENTIFIC REPORTS

OPEN

Role of dimensionality in complex networks

Samuraí Brito[1], L. R. da Silva[1,2] & Constantino Tsallis[2,3]

Aim: to explore d-dimensional geographically located networks which grow with preferential attachment involving Euclidean distances through $r_{ij}^{-\alpha_A}$ $(\alpha_A \geq 0)$.

GROWTH MODEL

$$P_G(r) \propto \frac{1}{r^{2+\alpha_G}} \longrightarrow P_G(r) \propto \frac{1}{r^{d+\alpha_G}}$$

$r \geq 1$ is the Euclidean distance from the newly arrived site to the center of mass of the pre-existing system, namely,

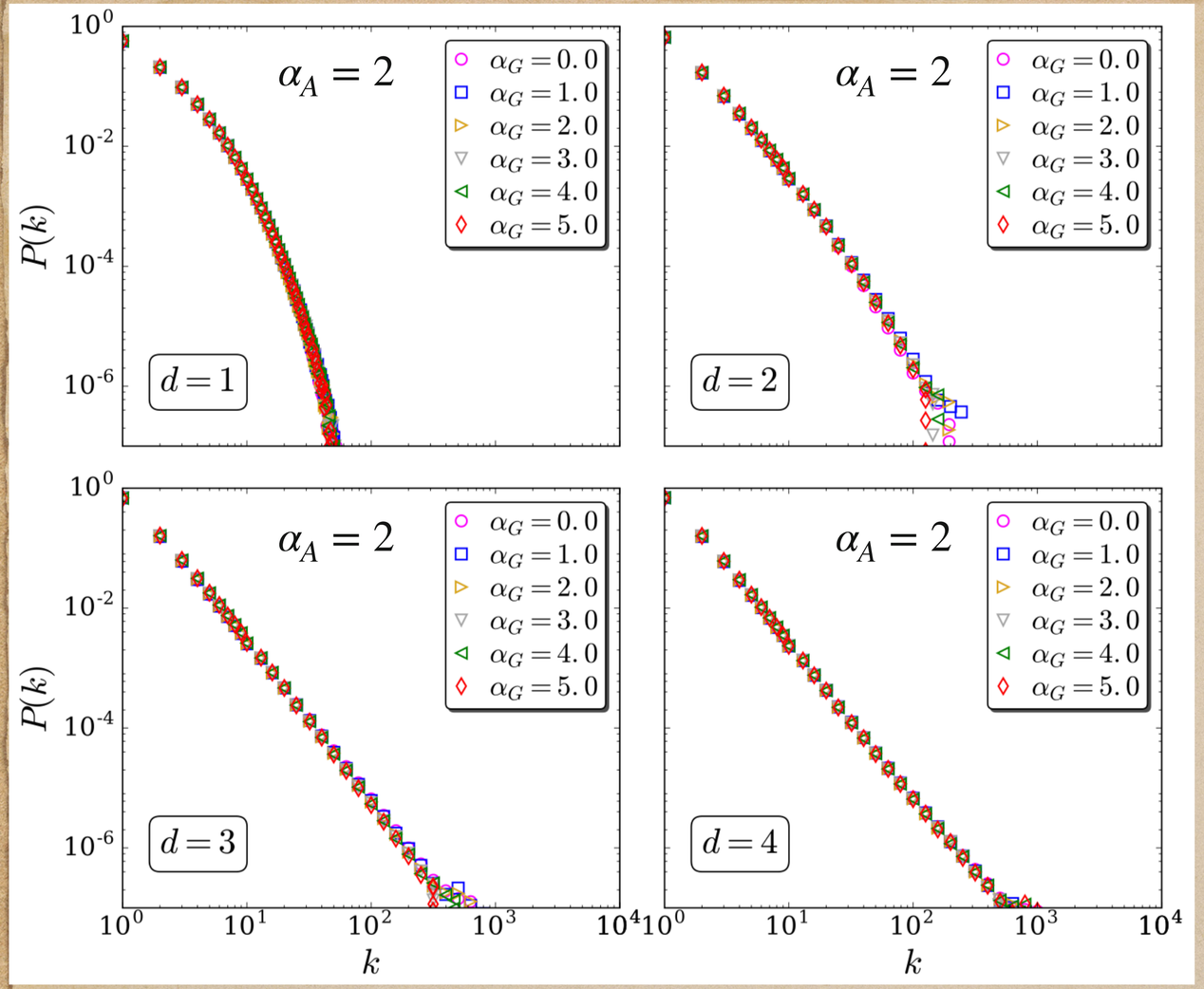
in 1d $\longrightarrow$ $r = x$

in 2d $\longrightarrow$ $r = \sqrt{x^2 + y^2}$

in 3d $\longrightarrow$ $r = \sqrt{x^2 + y^2 + z^2}$

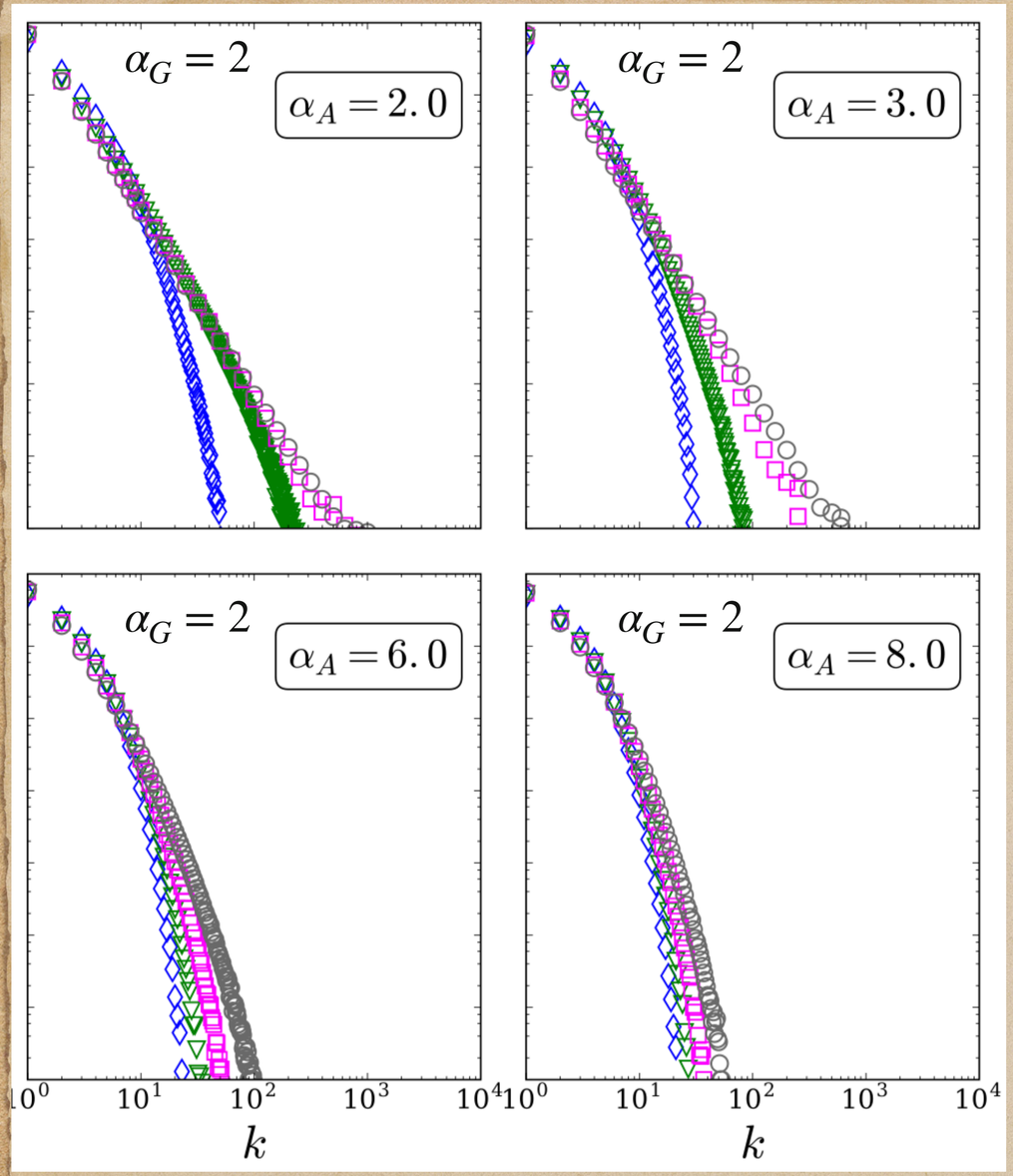
Preferential attachment probability

$$p_A = \frac{k_i \, r_{ij}^{-\alpha_A}}{\sum_{j=1}^{N-1} k_j \, r_{ij}^{-\alpha_A}} \quad \in [0,1]$$



$P(k)$ distribution is independent of α_G for all dimensions.

Brito, da Silva and Tsallis, Sci. Rep. 6 (2016) 27992.

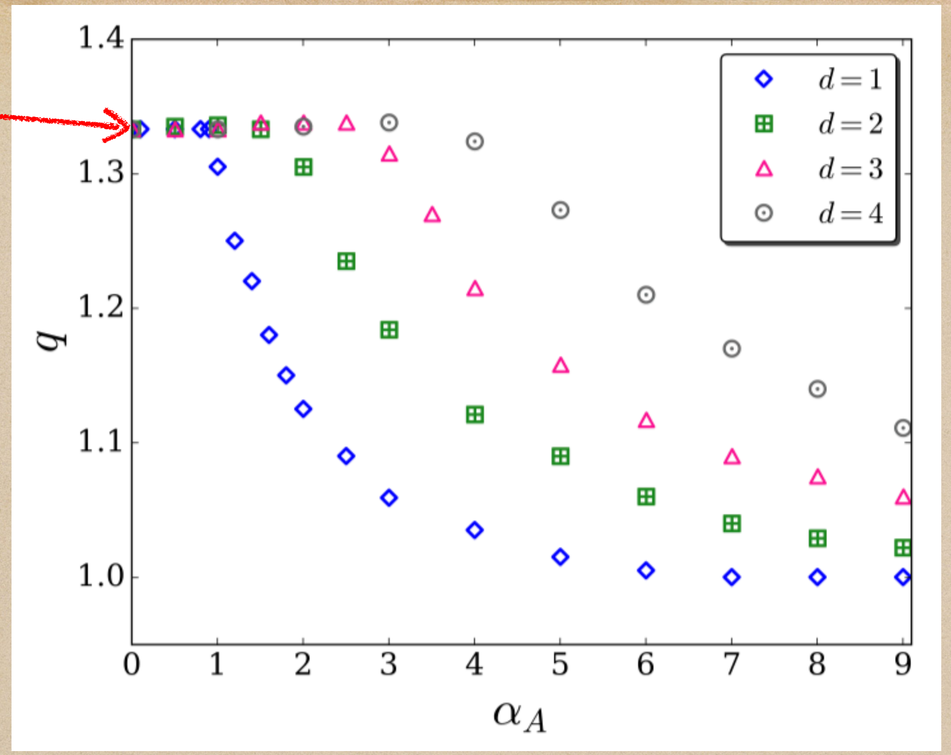


On the other hand, $P(k)$ distribution is dependent of α_A for all dimensions.

Each color indicates different dimensions.

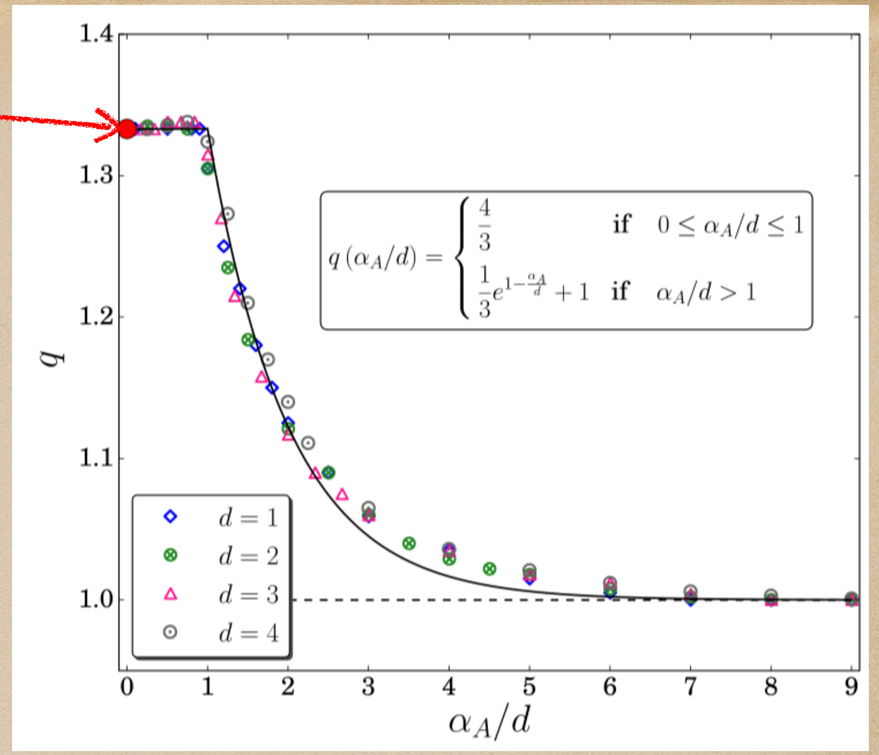
Brito, da Silva and Tsallis, Sci. Rep. 6 (2016) 27992.

BA



q *versus* α_A

BA



q *versus* α_A/d

Brito, da Silva and Tsallis, Sci. Rep. 6 (2016) 27992.

EPISODE 3

Exploring 'energy' distribution

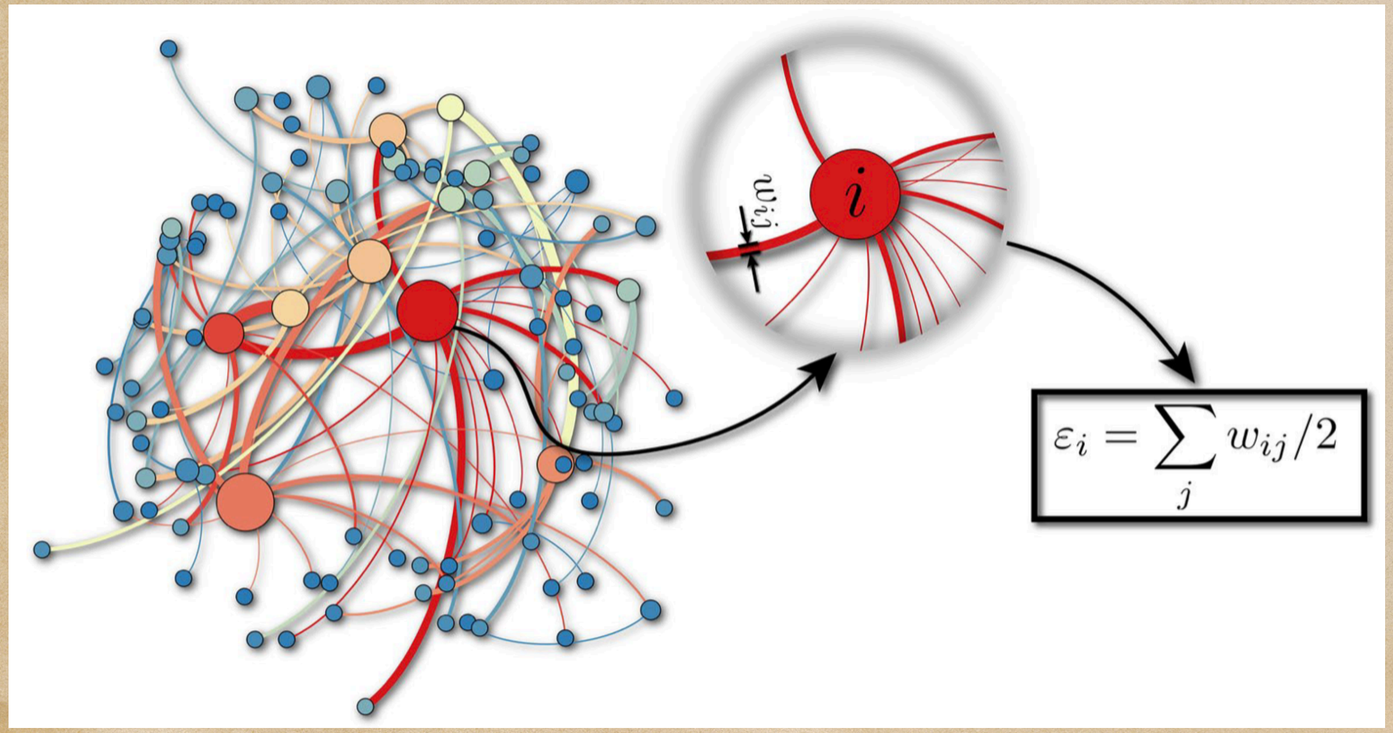
scientific reports

Check for updates

OPEN

Connecting complex networks to nonadditive entropies

R. M. de Oliveira[1], Samuraí Brito[2]✉, L. R. da Silva[1,3] & Constantino Tsallis[3,4,5,6]



Hubs emerge in the network

Each link has a specific width w_{ij}

'Energy' ε_i of a site i is given by the half of the sum over all link widths connected that site.

GROWTH MODEL

- Locate each site using probability $P_G(r) \propto \frac{1}{r^{d+\alpha_G}}$

- Choose a random number from a distribution $P(w)$ which gives the corresponding link weight.

  Energy of a site depends on how many links it has (k_i) and the widths of those links ($\{w_{ij}\}$).

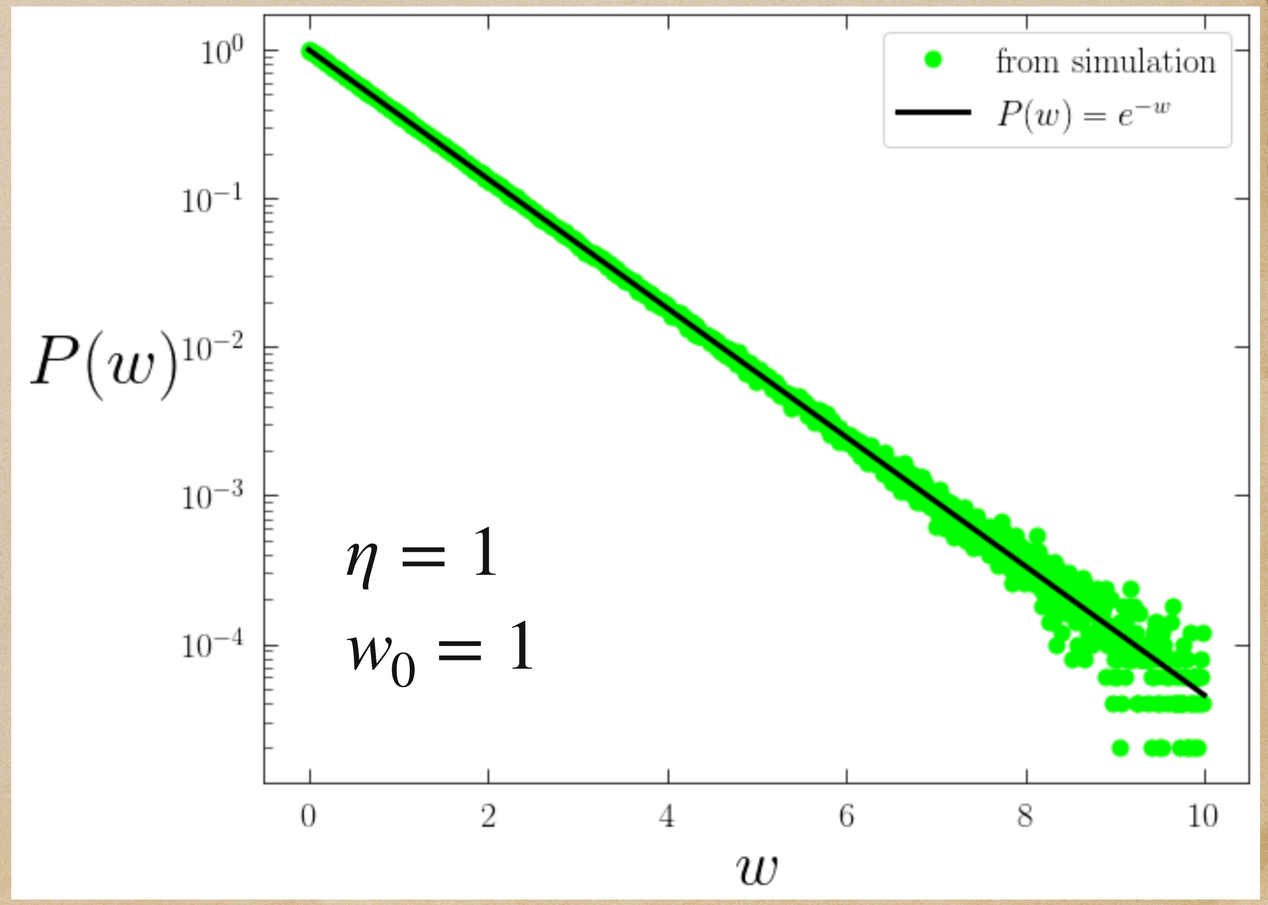
- Sites $i = 3,4,\ldots$ will be linked to the previous ones with probability

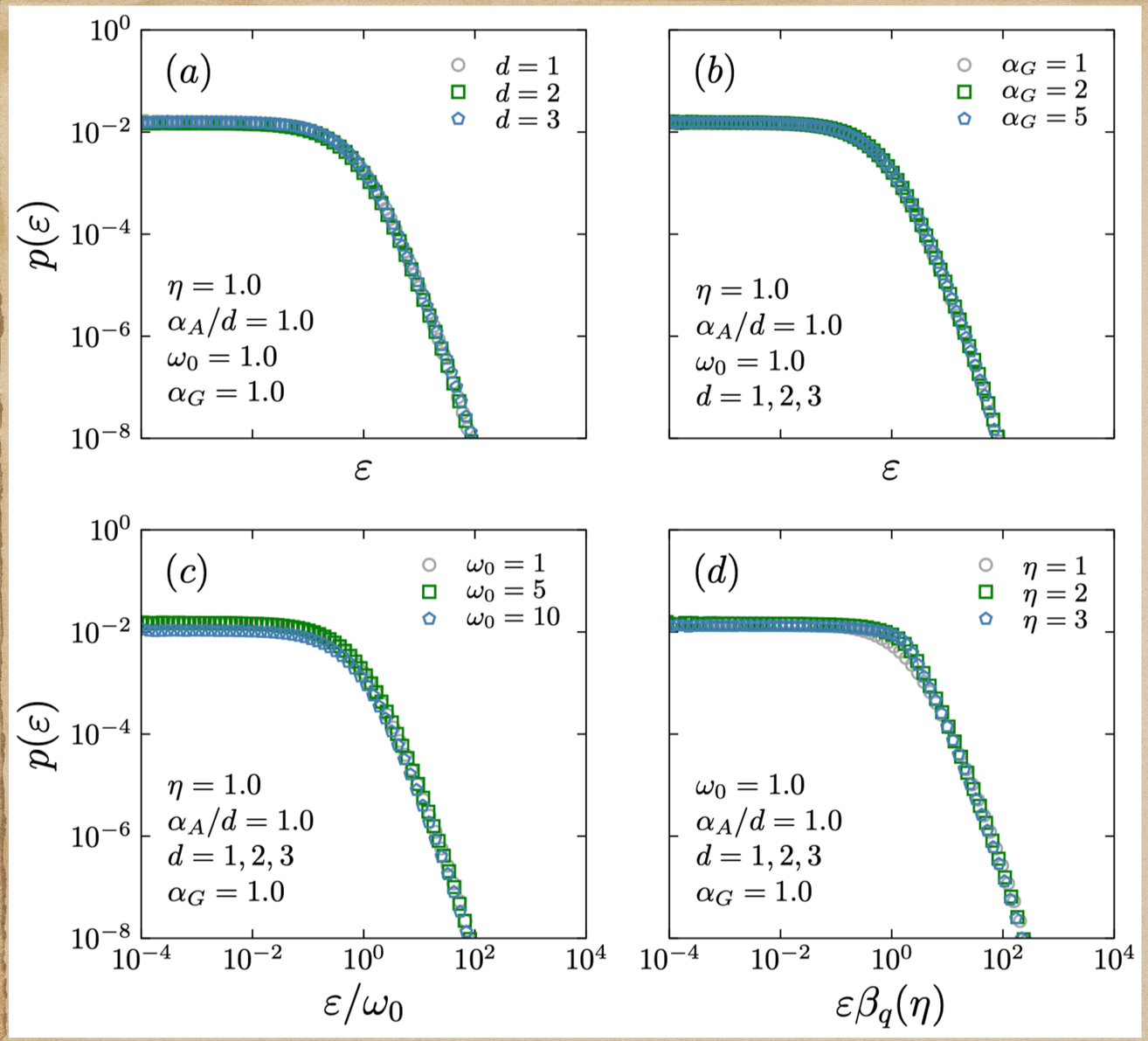
$$\Pi_{ij} \propto \frac{\varepsilon_i}{r_{ij}^{\alpha_A}}$$

GROWTH MODEL

Let's take the case where w is given by the stretched-exponential distribution:

$$P(w) = \frac{\eta}{w_0 \Gamma(1/\eta)} e^{-(w/w_0)^\eta}$$



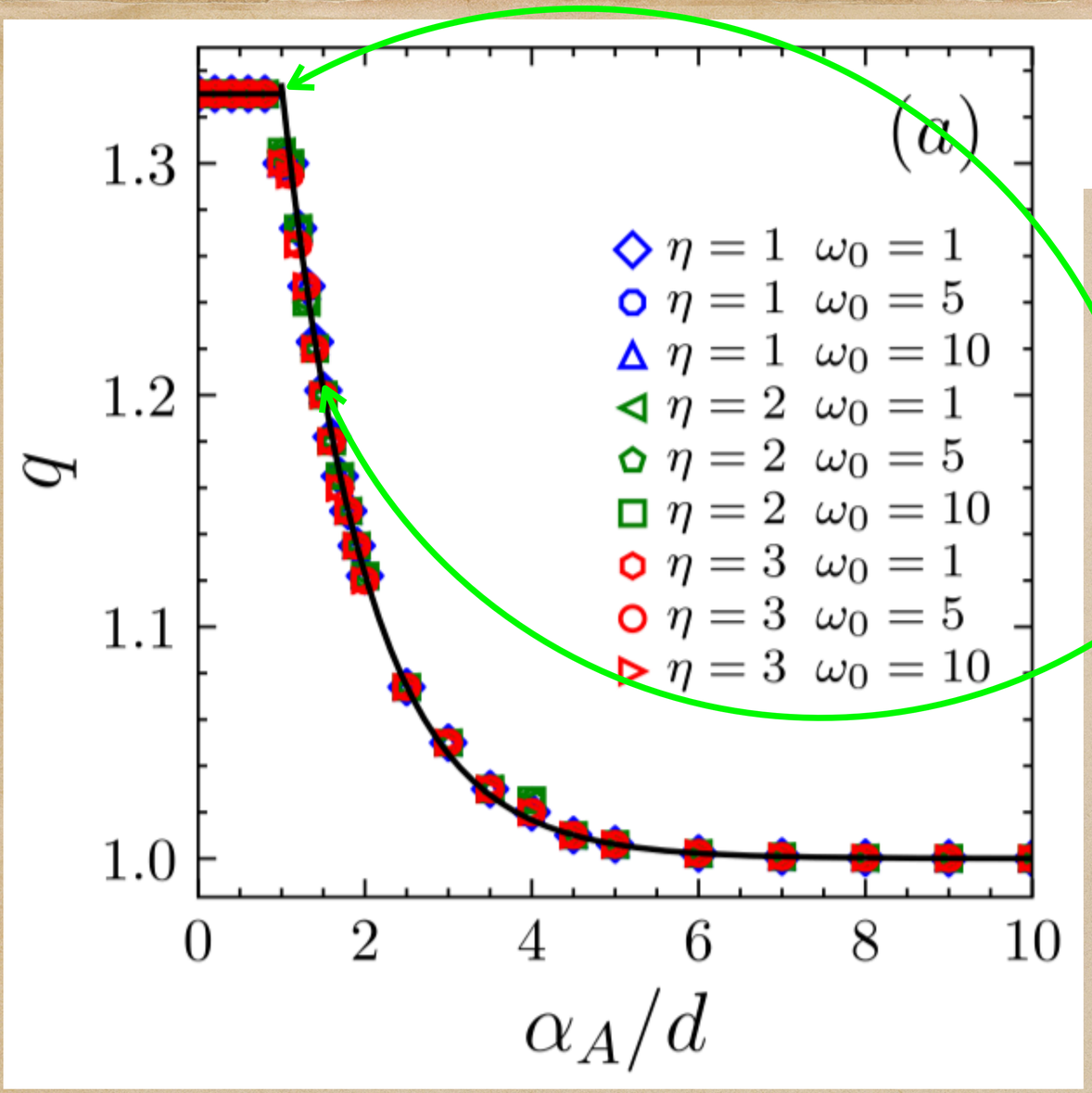


q-exponentials are good also to fit these results.!!

$$P(k) = P(0)\, e_q^{-\beta_q \varepsilon}$$

$$e_q^x = \left[1 + (1-q)x\right]^{1/(1-q)} \qquad (e_1^x = e^x)$$

de Oliveira et al., Sci. Rep. 11 (2021) 1130.



$$q = \begin{cases} \frac{4}{3} & \text{if } 0 \leq \frac{\alpha_A}{d} \leq 1 \\ \frac{1}{3}\, e^{1-\alpha_A/d} + 1 & \text{if } \frac{\alpha_A}{d} > 1 \end{cases}$$

For example :

$q = 1.333$ if $\alpha_A = 2$ for $d = 2$

$q = 1.202$ if $\alpha_A = 3$ for $d = 2$

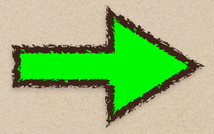
q versus α_A/d

de Oliveira et al., Sci. Rep. 11 (2021) 1130.

EPISODE 4

Exploring finite-size effects :

starts with this



Chaos ARTICLE scitation.org/journal/cha

Complex network growth model: Possible isomorphism between nonextensive statistical mechanics and random geometry

Cite as: Chaos 32, 053126 (2022); doi: 10.1063/5.0090864
Submitted: 9 March 2022 · Accepted: 2 May 2022 ·
Published Online: 19 May 2022

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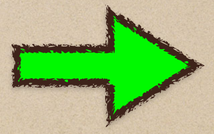
Constantino Tsallis[1,2,3,a)] and Rute Oliveira[4]

and more to come



Tirnakli&Tsallis, preprint (2023), in preparation.

FINITE-SIZE EFFECTS

Conjecture:

finite-size effects can satisfactorily be described by the equation:

$$\frac{d\xi}{d\varepsilon} = -\mu_r \xi^r - (\beta_q - \mu_r)\xi^q \qquad (r \le q\,;\ \varepsilon \ge 0)$$

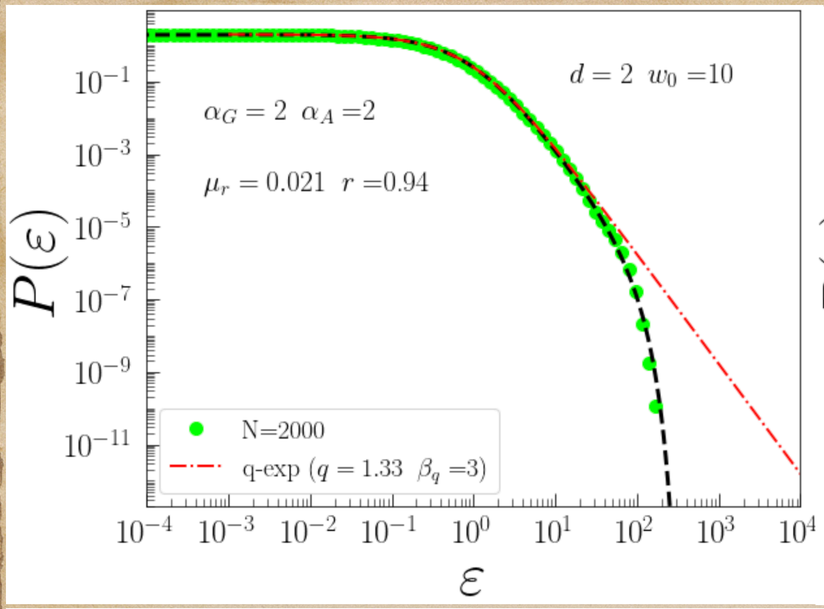
where

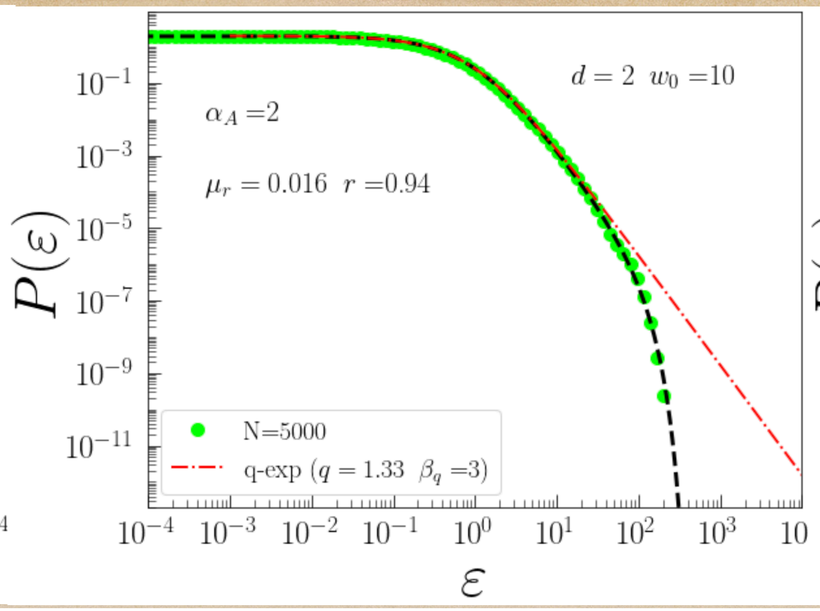
$$\xi(\varepsilon) = \frac{p(\varepsilon)}{(2-q)\beta_q}$$

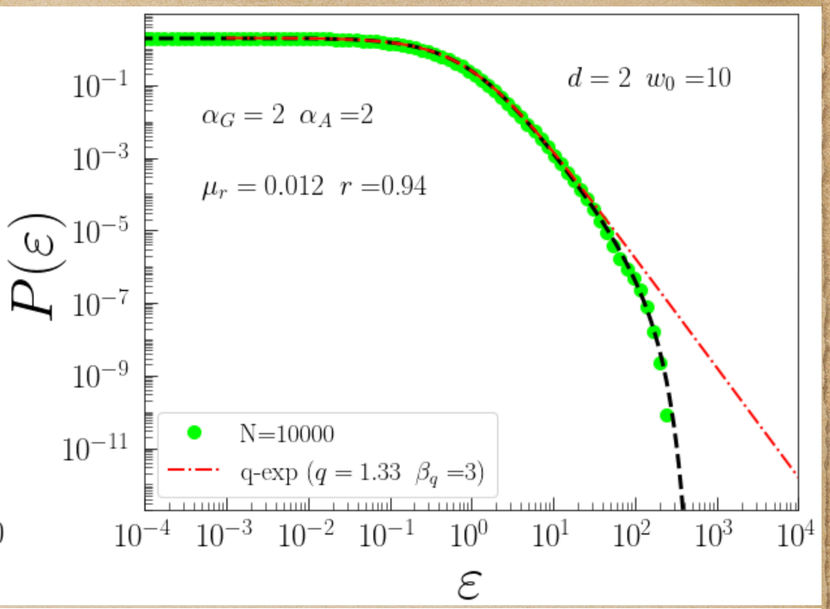
Consequently we have the solution as

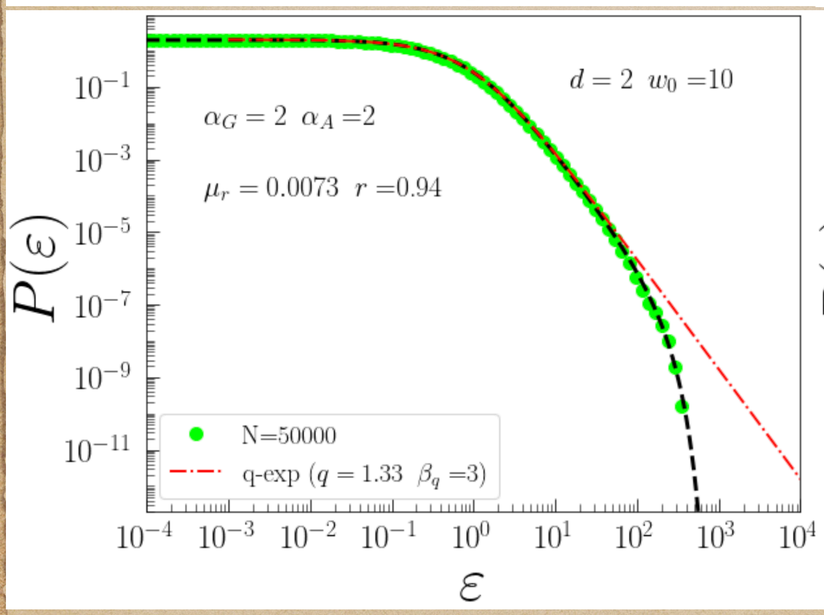
$$\varepsilon = \int_{\xi}^{1} \frac{dx}{\mu_r x^r + (\beta_q - \mu_r) x^q}$$

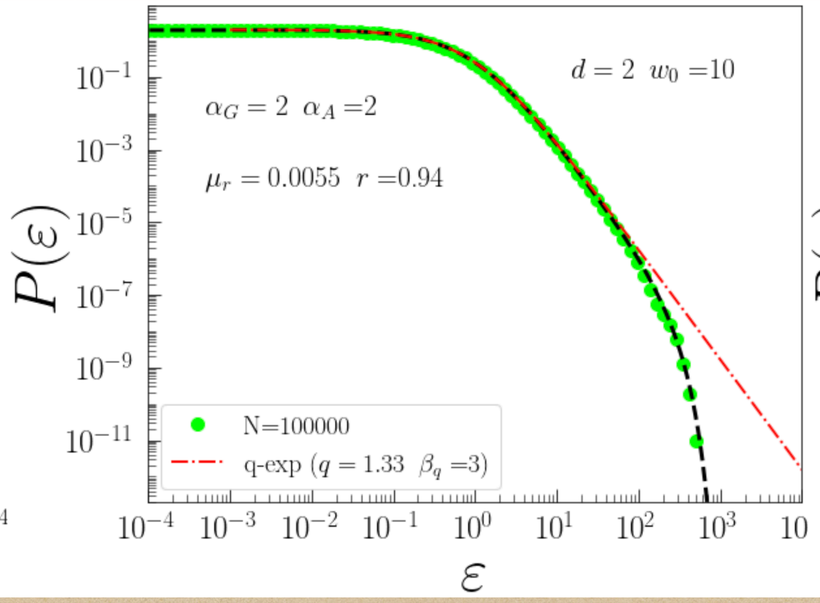
Numerically solve this integral

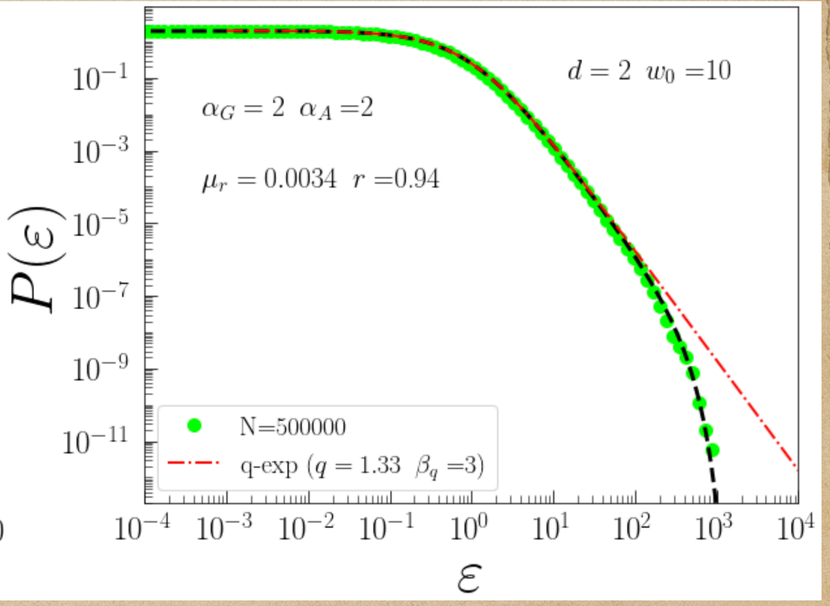




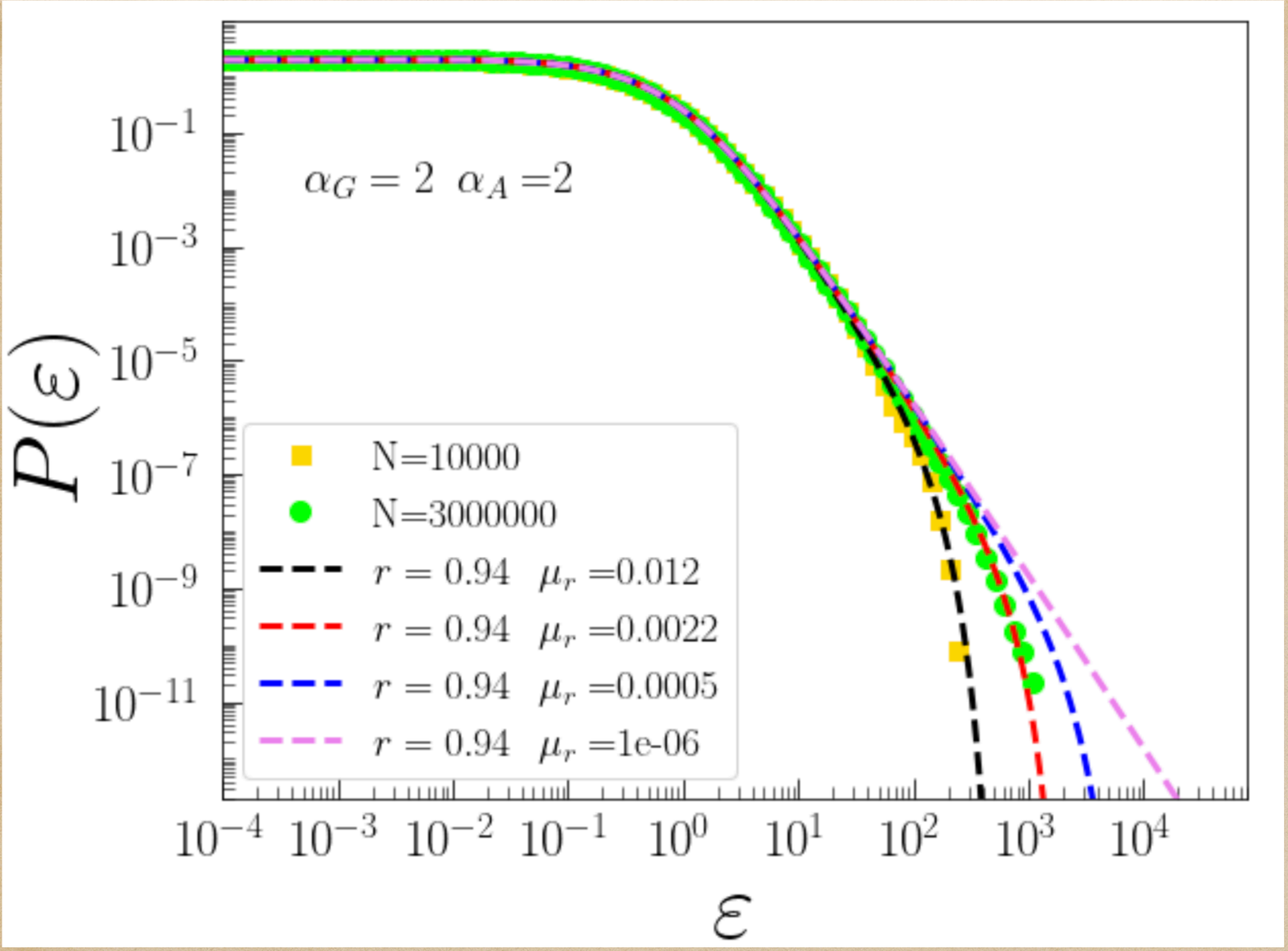






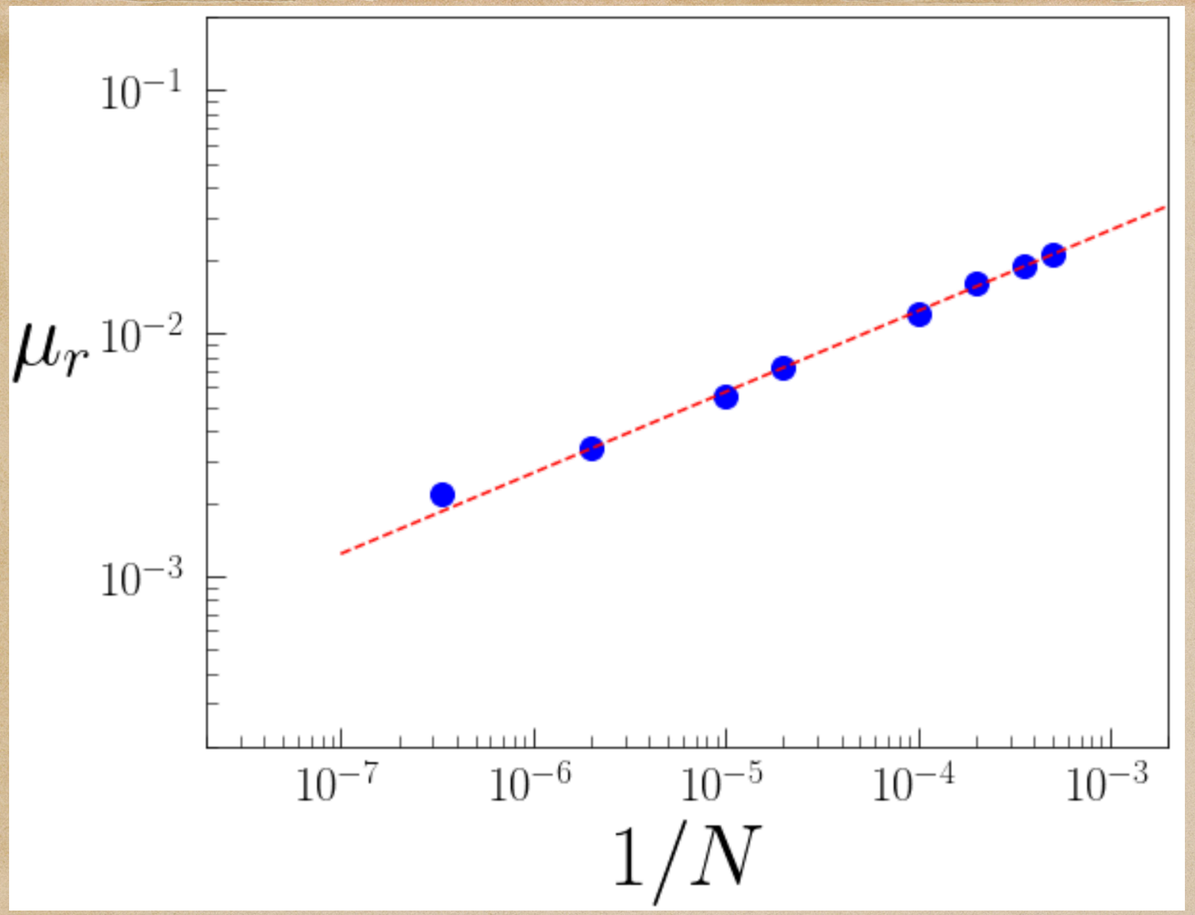


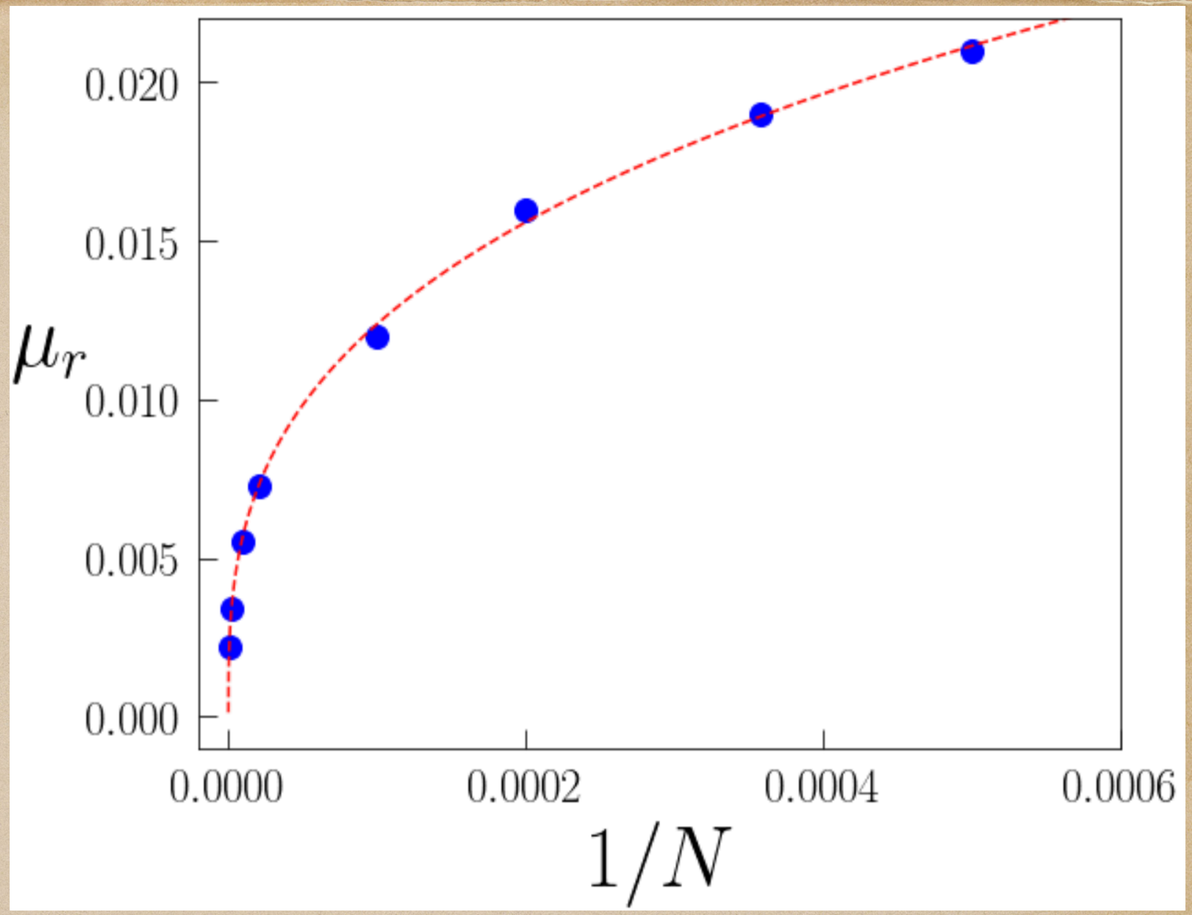
Tirnakli&Tsallis, preprint (2023), in preparation.



As N grows, the tendency to the exact q-exponential is evident.

Tirnakli&Tsallis, preprint (2023), in preparation.





As N grows, the tendency to the exact q-exponential is more evident here.

Tirnakli&Tsallis, preprint (2023), in preparation.

EPISODE 5

Exploring *crossover phenomenon*

Tirnakli&Tsallis, preprint (2023), in preparation.

CROSSOVER PHENOMENON

REMEMBER → Conjecture:

finite-size effects can satisfactorily be described by the Eq.:

$$\frac{d\xi}{d\varepsilon} = -\mu_r \xi^r - (\beta_q - \mu_r)\,\xi^q \qquad (r \le q\,;\ \varepsilon \ge 0)$$

where

$$\xi(\varepsilon) = \frac{p(\varepsilon)}{(2-q)\,\beta_q}$$

Consequently we have the solution as

$$\varepsilon = \int_{\xi}^{1} \frac{dx}{\mu_r\, x^r + (\beta_q - \mu_r)\, x^q}$$

Numerically solve this integral

GROWTH MODEL

- Locate each site using probability $P_G(r) \propto \frac{1}{r^{d+\alpha_G}}$

- Choose a random number from a distribution $P(w)$ which gives the corresponding link weight.

  Energy of a site depends on how many links it has (k_i) and the widths of those links ($\{w_{ij}\}$).

- Sites $i = 3,4,\ldots$ will be linked to the previous ones with probability

$$\Pi_{ij} \propto \frac{\varepsilon_i}{r_{ij}^{\alpha_A}} \quad \rightarrow \quad \Pi_{ij} \propto \frac{\varepsilon_i}{r_{ij}^{\alpha_A} + c\, r_{ij}^{\gamma_A}}$$

GROWTH MODEL

$$\Pi_{ij} \propto \frac{\varepsilon_i}{r_{ij}^{\alpha_A} + c\, r_{ij}^{\gamma_A}}$$

If $c = 0$, previous case is obtained :

$$\Pi_{ij} \propto \frac{\varepsilon_i}{r_{ij}^{\alpha_A}}$$

This corresponds one q-exponential depending on α_A .

If c is too large, then

$$\Pi_{ij} \propto \frac{\varepsilon_i}{c\, r_{ij}^{\gamma_A}}$$

This corresponds another q-exponential depending on γ_A .

CROSSOVER PHENOMENON

Conjecture:

crossover phenomenon together with finite-size effects can satisfactorily be described by the equation:

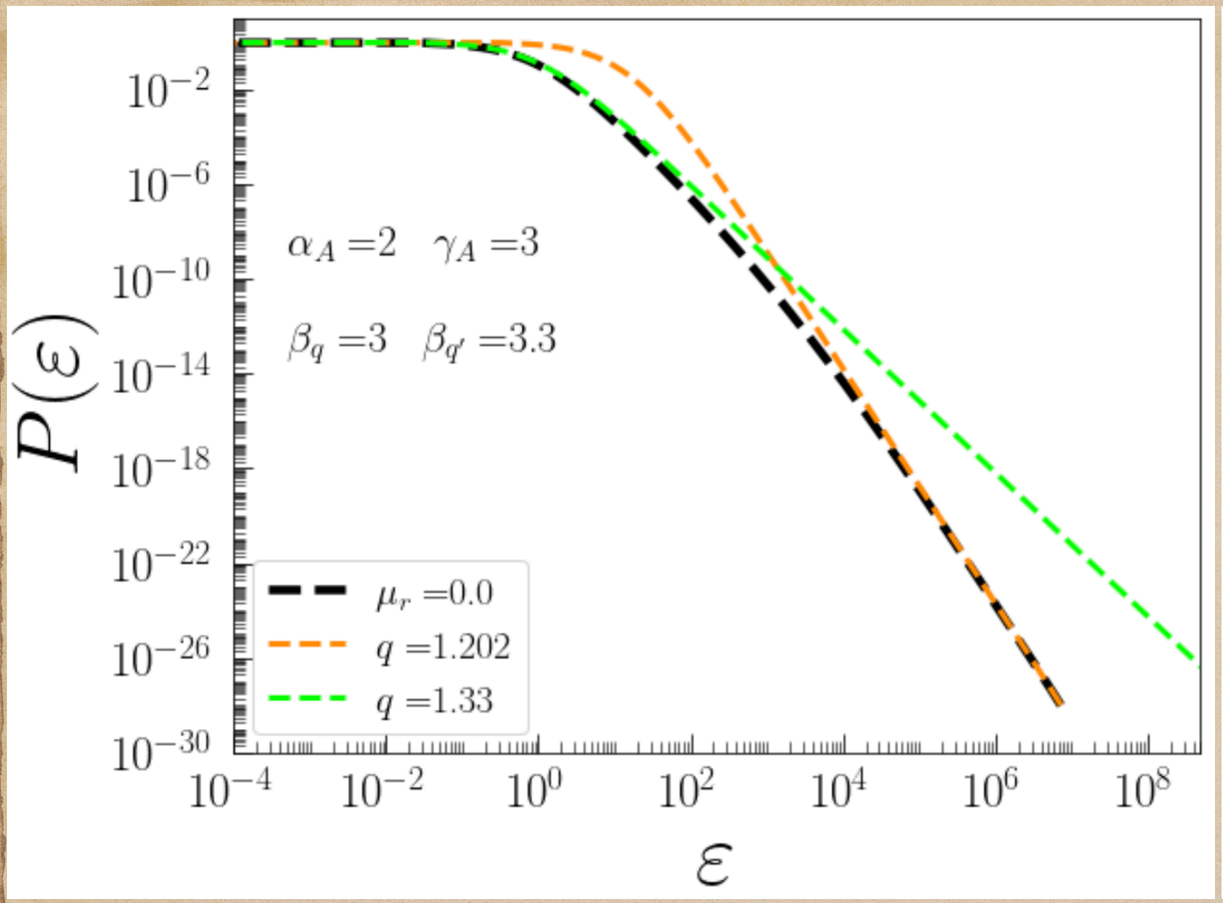
$$\frac{d\xi}{d\varepsilon} = -\mu_r \xi^r - (\beta_q - \mu_r)\xi^q - (\beta_{q'} - \beta_q + \mu_r)\xi^{q'}$$

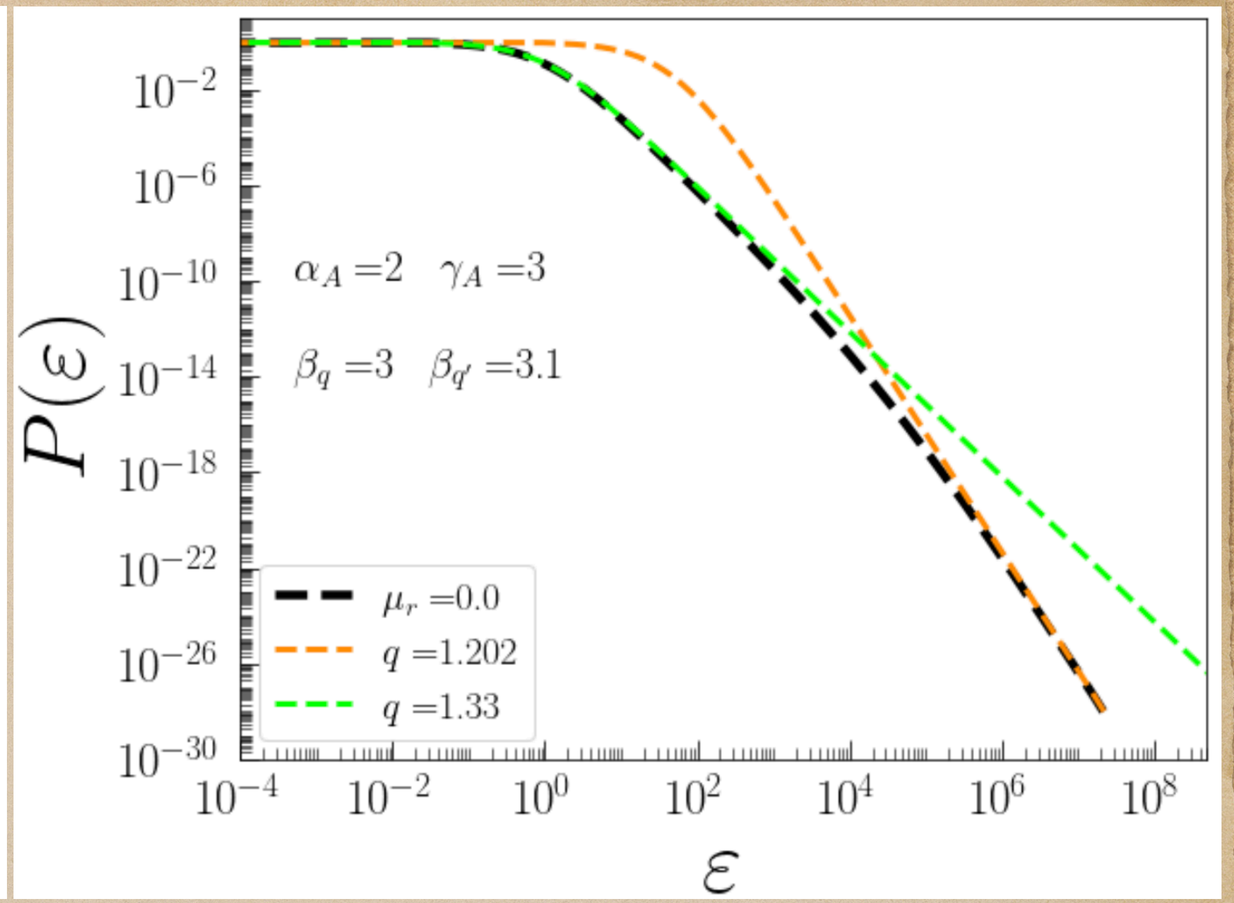
where $\xi(\varepsilon) = \dfrac{p(\varepsilon)}{(2-q)\beta_q}$

Consequently we have the solution as

$$\varepsilon = \int_{\xi}^{1} \frac{dx}{\mu_r x^r + (\beta_q - \mu_r)x^q + (\beta_{q'} - \beta_q + \mu_r)x^{q'}}$$

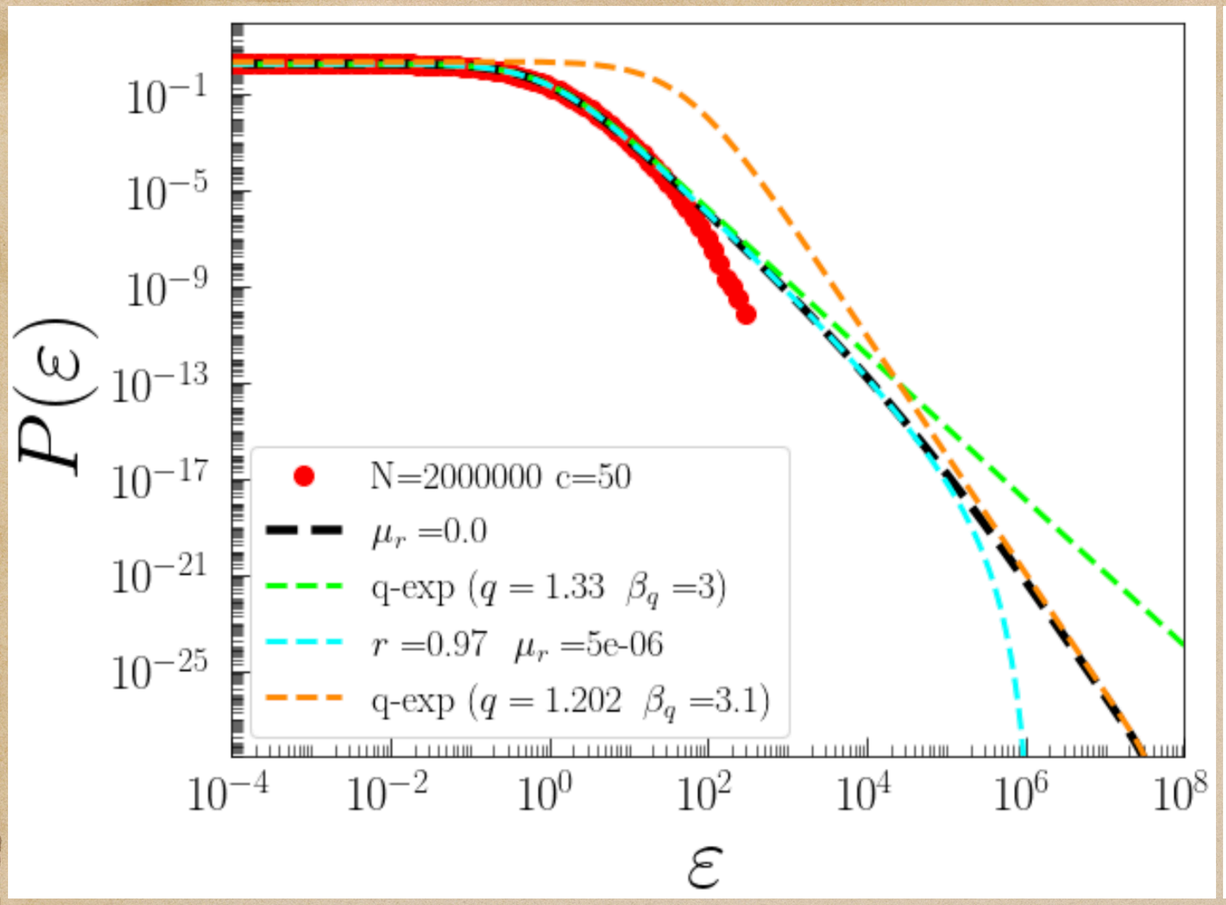
Numerically solve this integral

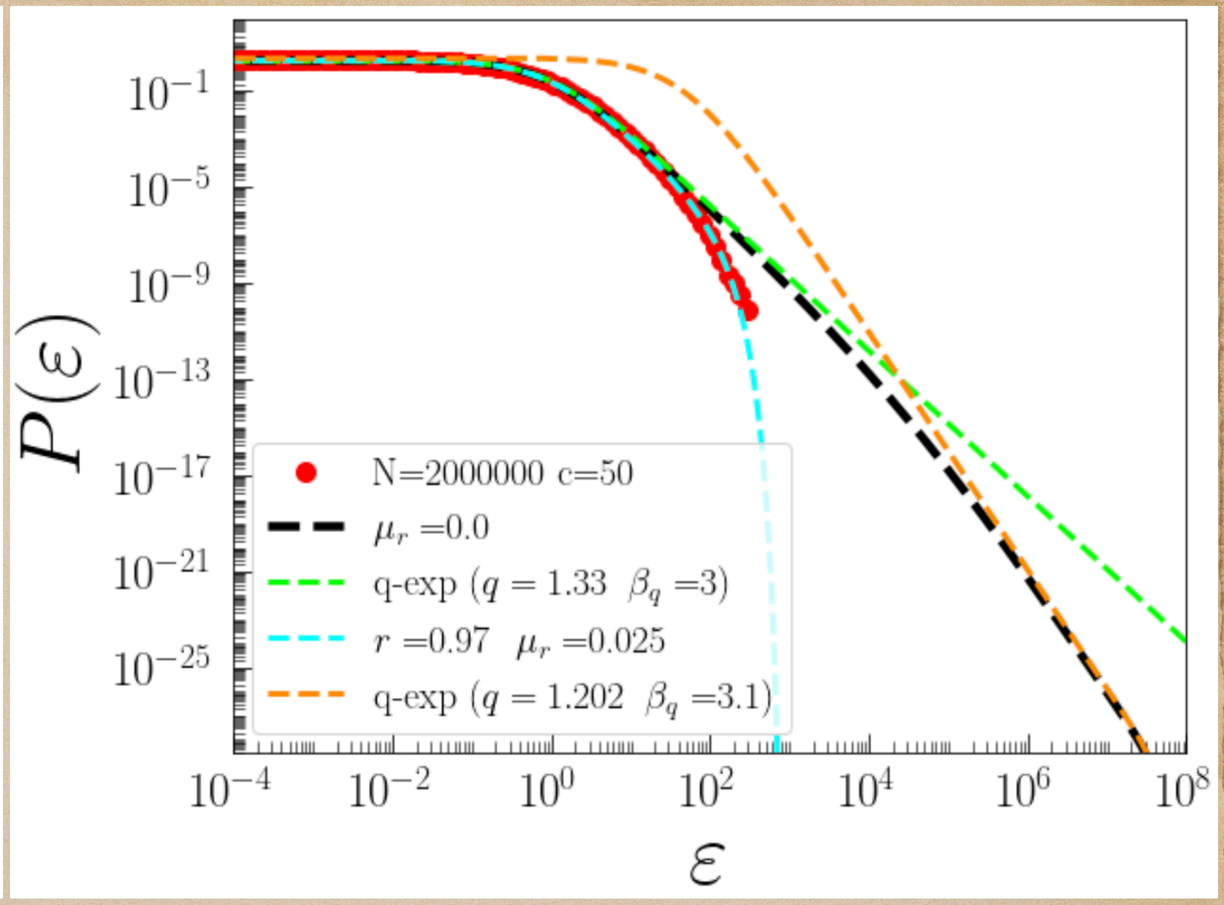




$q = 1.333$ if $\alpha_A = 2$ for $d = 2$

$q = 1.202$ if $\gamma_A = 3$ for $d = 2$





. . . more to come soon . . .

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Nonadditive Entropies and Nonextensive Statistical Mechanics—Dedicated to Professor Constantino Tsallis on the Occasion of his 80th Birthday

Guest Editors

Ugur Tirnakli, Christian Beck, Hans J. Herrmann, Airton Deppman, Henrik Jeldtoft Jensen, Evaldo M. F. Curado, Fernando D. Nobre, Angelo Plastino, Astero Provata and Andrea Rapisarda

Deadline

31 December 2023

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Special Issue

Invitation to submit

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Andrea Rapisarda

Deadline for manuscript submissions:
31 December 2023

Message from the Guest Editors

The aim of this Special Issue is to collect original research articles on the most recent research in nonadditive entropies and nonextensive statistical mechanics with their applications in physics and elsewhere, as well as comprehensive review articles covering these topics from a theoretical, experimental, or computational viewpoint.

This generalization of the centennial Boltzmann-Gibbs statistical mechanics and of the entropy upon which it is based were proposed in 1988 and have received, since then, many applications in natural, artificial, and social sciences. The undeniable success of the Boltzmann-Gibbs theory is deeply related to strongly chaotic nonlinear dynamical systems. In particular, for classical systems, the standard requirement is that the maximal Lyapunov exponent is positive. At the edge of chaos, where the maximal Lyapunov exponent vanishes, the need emerges for nonadditive entropies and consistent generalizations of quantities such as the Maxwellian distributions of velocities, the celebrated Boltzmann-Gibbs weight for energies, and Pesin-like identities. This generalized theory has received uncountable validations in complex systems.

Professor Constantino Tsallis has had an outstanding global impact on physics, astrophysics, geophysics, economics, mathematics, and computational sciences, among others. In recognition of his extraordinarily creative and productive scientific life and innumerable contributions to the field of statistical physics of complex systems, this Special Issue is dedicated to him on the occasion of his 80th birthday (5 November 2023).

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Special Issue

entropy

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Editor-in-Chief

Prof. Dr. Kevin H. Knuth
Department of Physics, University at Albany, 1400 Washington Avenue, Albany, USA

Message from the Editor-in-Chief

The concept of entropy is traditionally a quantity in physics that has to do with temperature. However, it is now clear that entropy is deeply related to information theory and the process of inference. As such, entropic techniques have found broad application in the sciences.

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HOME ABOUT CONSTANTINO REGISTRATION PROGRAMME IMPORTANT DATES PARTICIPANTS SPECIAL ISSUE ADDITIONAL INFORMATION

MY TALK

STATISTICAL MECHANICS FOR COMPLEXITY

A CELEBRATION OF THE 80TH BIRTHDAY OF CONSTANTINO TSALLIS

RIO DE JANEIRO, 6 TO 10 NOVEMBER 2023

~~1st part~~

~~about PHYSICS~~

2nd part

about HISTORY

A SCIENTIFIC LIFE WITH CONSTANTINO

Story begins in 1997 when he visited us in Izmir during my PhD

(no photo is available from that archaic time 😀).

Then, at the end of my PhD, I received a scholarship from TUBITAK for a short visit to CBPF in 1998.

1st joint paper

Eur. Phys. J. B **11**, 309–315 (1999)

THE EUROPEAN PHYSICAL JOURNAL B

EDP Sciences

Circular-like maps: sensitivity to the initial conditions, multifractality and nonextensivity

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A SCIENTIFIC LIFE WITH CONSTANTINO

During my 1-month stay there, we have discussed various subjects but one day he told me:

"Ugur, if you continue your career in statistical mechanics, surely you will not be a rich guy, but I assure you that you will enjoy it".!!!

A SCIENTIFIC LIFE WITH CONSTANTINO

Then he immediately offered to me a Post-doc position supported by CNPq (and also by TUBITAK).

Then, I end up in a one-year Postdoc position in CBPF in 1999-2000.
(starting to enjoy life 🥳🧿)

A SCIENTIFIC LIFE WITH CONSTANTINO

After finishing my post-doc period there, I became an Ass. Prof. in Izmir at Ege Uni.

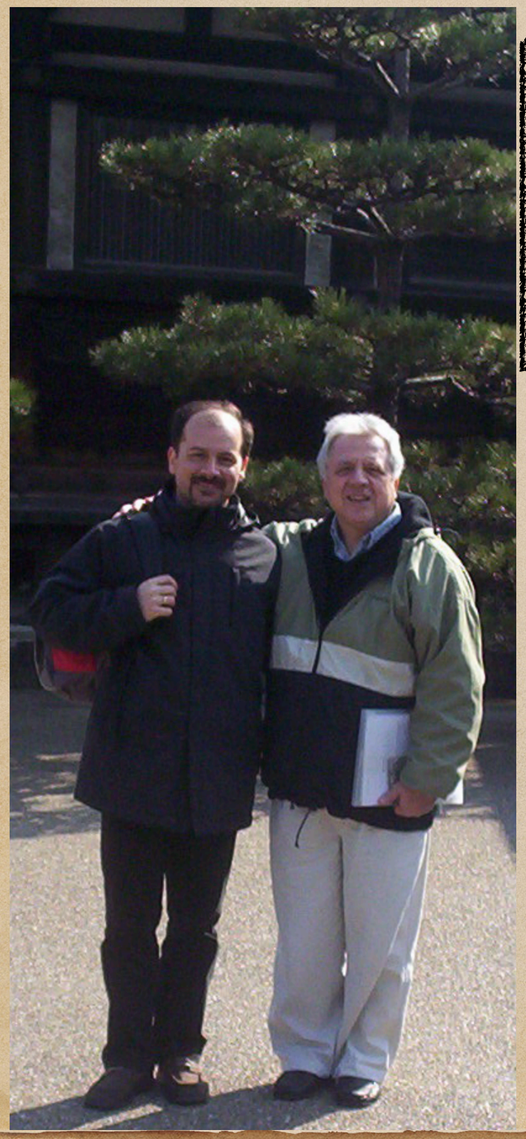
But, we keep on collaborating since then without any interruption.

During the Conference
"International School and Conference on Nonextensive Thermodynamics and Physical Applications", Villasimius, Italy, Summer 2001.

A SCIENTIFIC LIFE WITH CONSTANTINO

During the Workshop
"Trends and Perspectives on Extensive and Non-extensive Statistical Mechanics",
Angra dos Reis, Brazil, 2003.

A SCIENTIFIC LIFE WITH CONSTANTINO



During the Conference "Complexity and Nonextensivity: New Trends in Statistical Mechanics", Kyoto, Japan, March 2005.

... several conferences ...

During the Conference "Complexity, Metastability and Nonextensivity", Erice, Italy, Summer 2004.

A SCIENTIFIC LIFE WITH CONSTANTINO

During the Conference "LAWNP'09 ", Buzios, 2009.

... more conferences ...

During the Conference "STATPHYS", Genova, Italy, 2007.

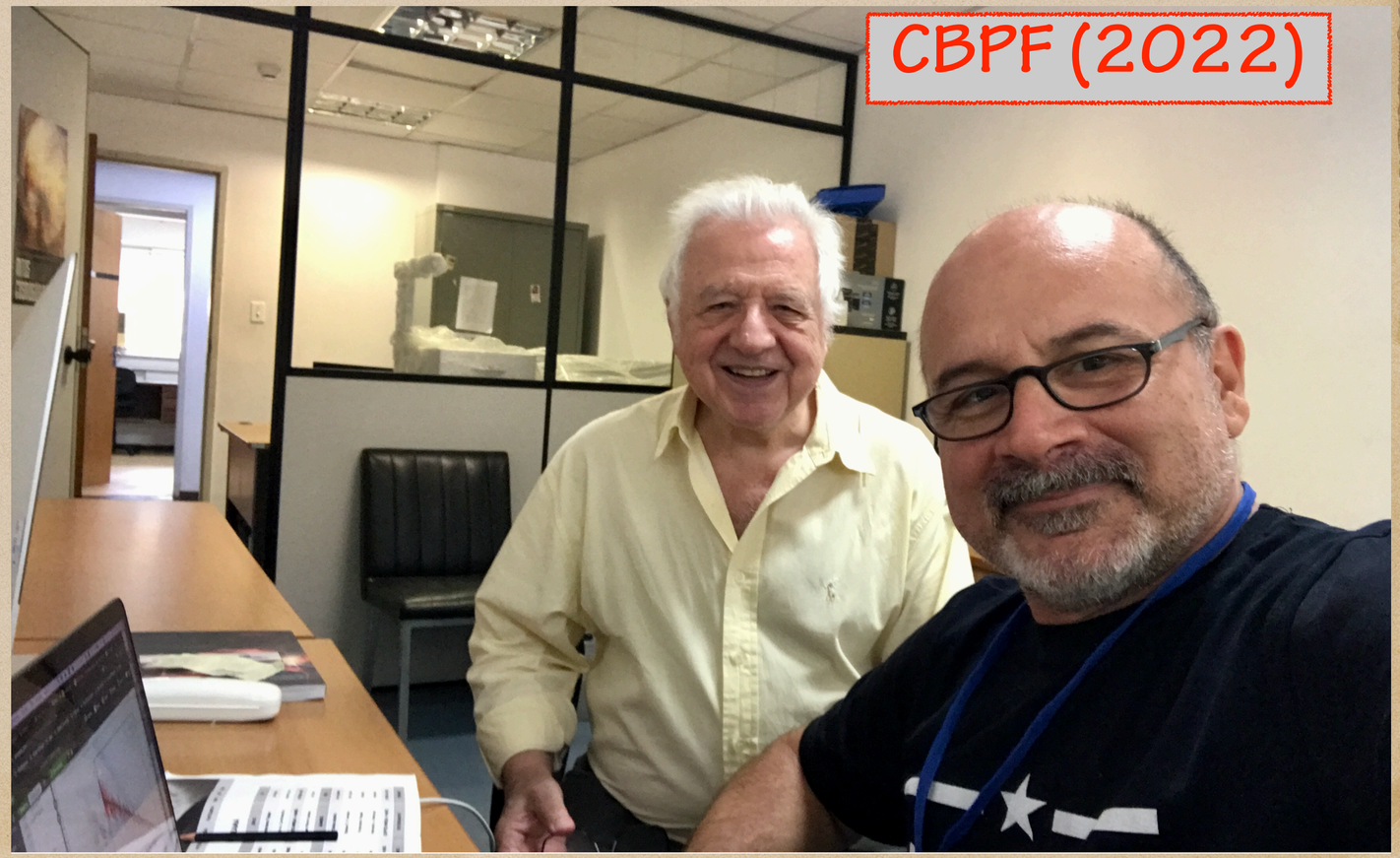
A SCIENTIFIC LIFE WITH CONSTANTINO

. . . as you see, sometimes we were working hard . . .

During the Conference
"School and Conference on Complex Systems and Nonextensive Statistical Mechanics", Trieste, Italy, Summer 2006.

A SCIENTIFIC LIFE WITH CONSTANTINO

. . . not only in those days we were young, bu also recently as we are getting older . . .



A SCIENTIFIC LIFE WITH CONSTANTINO

. . . but there are even other difficult times that we were even working harder . . .

During the Conference
"3. International Conference NEXT-SigmaPhi: News, Expectations and Trends in Statistical Physics", Crete, Greece, Summer 2005.

A SCIENTIFIC LIFE WITH CONSTANTINO

. . . even harder . . .

During the Conference
"Greek-Turkish Meeting on
Statistical Mechanics and Dynamical
Systems", Turunç, Turkey, Summer 2008.

A SCIENTIFIC LIFE WITH CONSTANTINO

. . . even exceptionally harder . . .

During the Conference

"International Workshop on Foundations of Complexity", Rio, Brazil, October 2015.

During the Conference

"International School on Complexity", Erice, Italy, 2015.

A SCIENTIFIC LIFE WITH CONSTANTINO

. . . as time goes by, we arrived 2013, remember?

A SCIENTIFIC LIFE WITH CONSTANTINO

. . . then we realized that we are getting older, and decided to work harder . . .

Rio 2016

Bodrum 2019

Istanbul 2019

A SCIENTIFIC LIFE WITH CONSTANTINO

… believe it or not, even harder …

Chios 2019

Rio 2019

Crete 2023

Istanbul 2019

A SCIENTIFIC LIFE WITH CONSTANTINO

… but don't think that we are just workaholic guys, we are also very good in sports …

Rio 2023

Rio, year unknown

Foz do Iguaçu 2008

A SCIENTIFIC LIFE WITH CONSTANTINO

. . . and finally . . .

Lagoa, Rio de Janeiro,

2023 (yesterday) 🥳

A SCIENTIFIC LIFE WITH CONSTANTINO

. . . and if I come back to my first slide . . .

During my 1-month stay there, we have discussed various subjects but one day he told me:

"Ugur, if you continue your career with statistical mechanics, surely you will not be a rich guy, but I assure you that you will enjoy it".!!!

!! 26 years !!
(20 papers)

YES CONSTANTINO,
ONCE AGAIN, YOU WERE RIGHT !! WE REALLY ENJOYED OUR LIFES,
AS YOU PROMISED, AND IT WAS REALLY A PLEASURE AND PRIVILEGE
FOR ME TO WALK TOGETHER DURING ALL THESE 26 YEARS.

obrigadao