WORKSHOP ON STATISTICAL PHYSICS

WOSP

N°1

GENERANDO ESPACIOS PARA VISIBILIZAR Y DISCUTIR LA INVESTIGACIÓN EN FÍSICA ESTADÍSTICA

Itaú

UNIVERSIDAD CATOLICA DEL NORTE CHILE

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GENERANDO ESPACIOS PARA VISIBILIZAR Y DISCUTIR
LA INVESTIGACIÓN EN FÍSICA ESTADÍSTICA

UNIVERSIDAD CATÓLICA DEL NORTE, ANTOFAGASTA

WoSP: Workshop On Statistical Physics

Creating spaces to highlight and discuss about statistical physics' research

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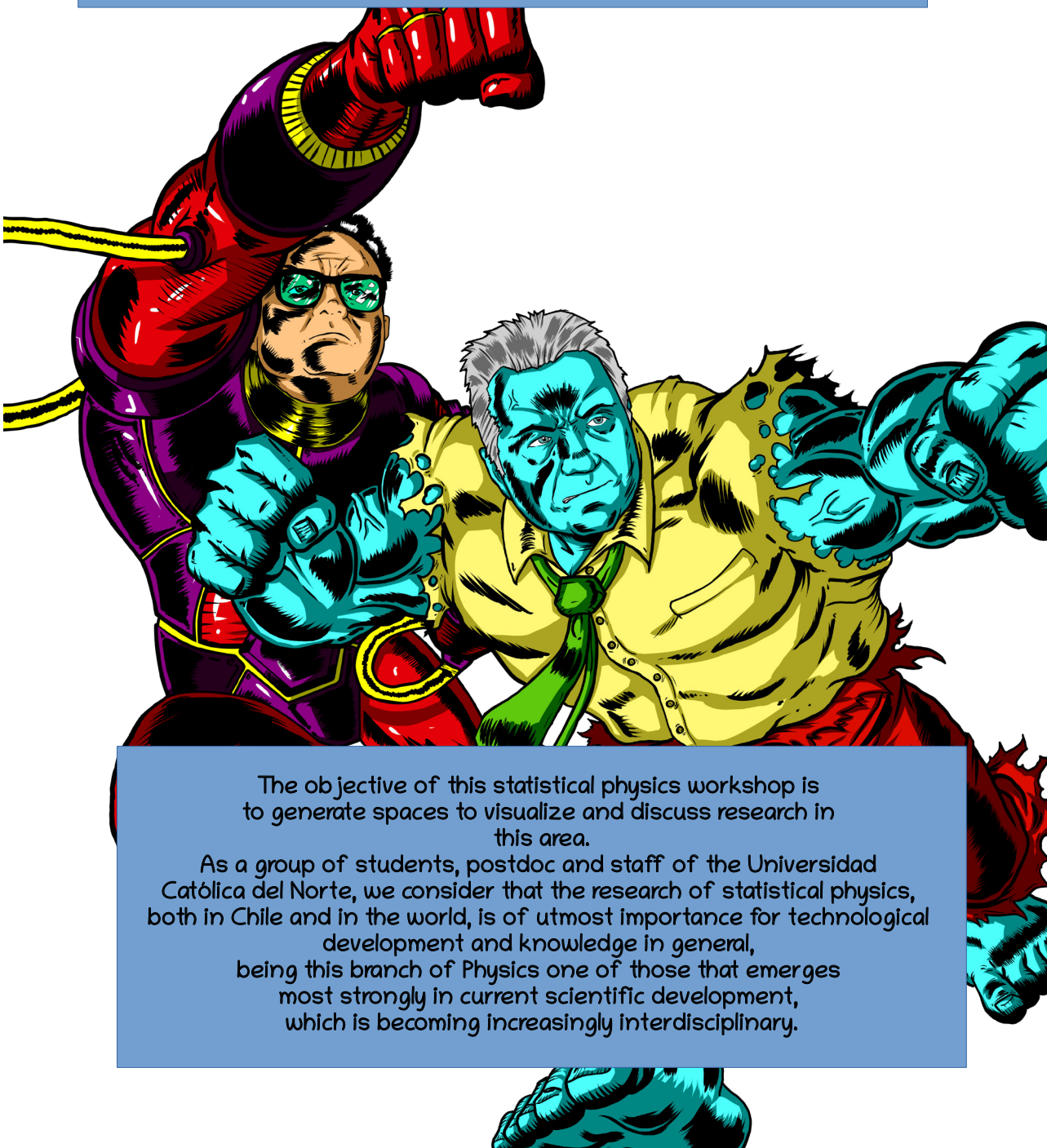
The academic purpose of these workshops is to be able to discuss ideas on contingent topics related to statistical physics, so that scientists can know the focus of the research carried out by their peers. Currently in Chile, Physical Statistics is not considered a science of central importance, which can be observed in cases such as the application for projects or general financing, where it's not possible to access directly with the statistical physical topic, being related to other areas and not achieving the visibility that it should have as a fundamental science.



The objective of this statistical physics workshop is to generate spaces to visualize and discuss research in this area.
As a group of students, postdoc and staff of the Universidad Católica del Norte, we consider that the research of statistical physics, both in Chile and in the world, is of utmost importance for technological development and knowledge in general, being this branch of Physics one of those that emerges most strongly in current scientific development, which is becoming increasingly interdisciplinary.

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M. Escobar, S. Curilef, F. Pennini

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S. Davis

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C. Abraham T. Chavez and Sergio Curilef

"Study and Analysis of chaos for a globally coupled map"
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"Rotating astrophysical system under an external potential well: A thermodynamic study of axial-symmetric solutions"
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Section IV: Non-Equilibrium Thermodynamics

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L. Velazquez

"Quantum approach to the second law of thermodynamics"
D.F. Mundarain, V. M. Apel, M. Orszag

"Predictive Statistical Mechanics: Jaynes's vision and a new foundation"
Sergio Davis

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"Cosmic-rays transport within Milky Way"
R. A. Lineros

"Understanding graphene and graphitic ZnO and ZnS nanofilms: A computational approach"
S. Conejeros and N. Allan

"Importance of theoretical and applied research in statistical physics with a focus on industry"
D. Gonzalez, S. Curilef and J. Hormazabal

Section VI: Complex Systems

"Nonlinear Reaction-Diffusion equation: A quantitative approach to the social outbreak in Chile 2019"
S. Curilef and D. González

"Characterization of written language using quantitative measures of word structuring"
F. A. Calderón and S. Curilef

"Complex systems methods applied to weather time series of Antofagasta, Chile."
H. Farfan, A. Castillo, S. Curilef and F. Pennini

Statistical Complexity, Disequilibrium, and thermodynamic relations

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Introducción

The disequilibrium concept D was introduced by López-Ruiz, Mancini, and Calbet 25 years ago, together with their successful notion of statistical complexity C [1]. The consensus is that the ensuing C is a statistical indicator that can yield different and perhaps deeper insights than purely dynamic ones. Certainly, this C is a quantifier that complements entropy S in the sense that it grasps correlation structures in the manner that S does it with disorder. The standard form for a measure of statistical complexity C becomes then $C = DS$.

In this research we will show that, in a classical phase-space context with continuous probability distributions, the notion of disequilibrium displays interesting thermodynamic properties and is able to replace the partition function. For such end, we will use the structures of the canonical-ensemble environment and will show that for classical integrable systems there is a consistent thermodynamic description related to it [2].

Agradecimientos: We acknowledge financial support from FONDECYT, grant 1181558.

Referencias

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Analysis of complexity for a bistable potential

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Introduction

Statistical complexity measures [1] have been applied in several fields and scientific branches, particularly, in the study of unpredictable and chaotic regimes in nonlinear systems. The objective of this work is to show the analytical representation and numerical calculation of entropies and statistical complexities, using the probability distribution of the lowest stationary states of a quantum particle subjected to a one-dimensional bistable potential [2].

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Predictive Statistical Mechanics: Jaynes's vision and a new foundation

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Introduction

In the 50s and 60s, Edwin T. Jaynes proposed a conceptual extension of Gibbs's statistical mechanics, then named as predictive statistical mechanics, and known today as the principle of maximum entropy (MaxEnt), strongly supported in the Bayesian interpretation of probability. In this extension, statistical mechanics is seen as the methodology to construct the less biased predictive models using incomplete information, provided by external restrictions to the system. In the vision of Jaynes, later refined by other authors, the Gibbs-Shannon-Jaynes entropy is the key piece that allows choosing the best distribution among a set of candidates compatible with the restrictions imposed.

In this presentation we will review elements commonly understood as Bayesian probability and the principle of maximum entropy from an alternative fundamental point of view, which considers the idea of estimation as the basis of inference, and dispenses with the idea of entropy and its maximization. This vision provides us with additional tools that could complement the exploration of the meaning of information and probability.

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Parallel computation using MPI-FORTRAN: an application to the computation of phase diagrams of non-linear dynamical systems ruled by ODE's

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Introduction

In the first part of this talk, we briefly explain the concept of parallel computing using MPI- FORTRAN and its potential applications to science and engineering. In the second part we show a

practical application to the computation of phase diagrams of the parameter plane of a semiconductor laser subject to opticall injection. By one hand, we report a new kind of discontinuous spiral [1, 2] of stable periodic orbits, compound of the intercalation of fish-like and cuspidal-like structures. On the other hand we report the existence of tricorn-like structures [3] of stable periodic orbits in the laser model (a continuous time dynamical system). These tricorns born through simple Shi'lnikov bifurcations and exhibit a phenomenon of codimension-3 rotating in clockwise and anti-clockwise directions in the plane (K, ω). Our numerical results open new possibilities for optical switching between several different outputs of the laser in the neighborhood of these structures.

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[3] J. Milnor, Remarks on Iterated Cubic Maps Experimental Mathematics 1, 5 (1992).

Study and Analysis of chaos for a globally coupled map

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Introduction

Two techniques of space-time chaos control proposed by Braiman et al. (1995) and Qi et al. (2003) are studied. Both techniques, by the introduction of disorder, achieve an order in the coupled system. Based on this, a purely statistical study and analysis is carried out in order to characterize the chaotic and non-chaotic state with these two techniques.

References

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A general statistical model for waiting times until the system collapses

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Introduction

The distribution of waiting times until the occurrence of a critical event is a crucial problem in statistics for various disciplines in science. They have been observed and studied, for example, in the Earth behavior in the case of earthquakes, cell damage in case of death, stochastics processes in finance, to name a few. These phenomena can be understood in terms of the gradual accumulation of some amount, which also gives them relevance for technological applications, for example, in the study of damages in the structure of materials, damage in biological matter induced by radiation, among others.

In this work we consider a statistical process in which a positive quantity X accumulates from zero in incremental steps, until X exceeds a threshold value X* that triggers the collapse. The distribution of the waiting time obtained corresponds to a composition of gamma distributions, which at the same time can be approximated to an effective gamma distribution as a division of a modified Bessel function.

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Existence of free energy and uniqueness of measures of Gibbs in spins models with random interactions

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Introduction

One of the main objectives of statistical mechanics is the deduction of macroscopic properties of a system based on the study of its microscopic properties. In this work we considered a one-dimensional model of spins, with a random Hamiltonian defined on a finite volume V, for $x \neq y$,

$$H_V[\sigma] = \frac{1}{2} \sum_{x \in V} \sum_{y \in V} \frac{J_{x,y} \sigma_x \sigma_y}{\left| x - y \right|^{a_{xy}}} \qquad (1)$$

Here $J_{x,y}$ is a collection of sub-Gaussian independent random variables and invariant distribution by translations. Random variables $a_{x,y}$ are assumed independent and identically distributed, with non-negative values. This work generalizes the papers originally published by Khanin, the most important results discussed are the existence of a non-random free energy and the uniqueness of Gibbs measurements for the model proposed in the thermodynamic limit. Some of the possible extensions and applications for an expansion in clusters are also discussed.

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Relationship between the average kinetic energy and the temperature out of equilibrium

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In this work, we apply the d-HMF model[1] to the study of the thermodynamics of systems with long-range interactions out of equilibrium. In this kind of systems are present the so-called Quasi-Stationary-States(QSS). In these states, the average kinetic energy remains constant during a time, but then they evolve towards the Boltzmann equilibrium. In recent works [1], we study this model by means of molecular dynamics simulations. Now, we are studying the dynamics of this system in the thermodynamic limit, by means of Vlasov dynamics. We found Vlasov solutions as Tsallis-like distribution, it is,

$$f(\mathbf{r}) = C(1-(1-q')\beta' e(\mathbf{r}))^{\frac{1}{1-q'}},$$

where r, are the positions and orientations, $e(r)$ is the energy of one particle, C is a normalization constant, q', and β are parameters. We noticed that the Boltzmann distributions cannot represent this profile, because the tails are weight. To find the solutions we used optimization procedure and variational methods[2]. The results reveal that only is valid the known relationship between temperature and average kinetic energy in the equilibrium for Tsallis-like distributions.

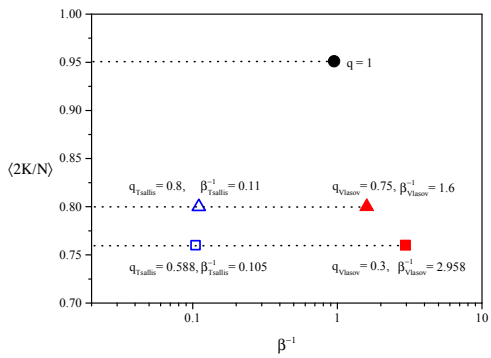

Figura 1: *Average kinetic energy by Tsallis and Vlasov distributions of the QSS and equilibrium regimes.*

Acknowledgment: Beca interna UCN, FONDECYT-Chile 1170834.

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Rotating astrophysical system under an external potential well: A thermodynamic study of axial-symmetric solutions

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Introduction

This research develops the thermo-statistical description of astrophysical systems during almost-stationary evolution. Our goal is the development of models that include the incidence of anisotropy in the thermodynamic behavior of an open astrophysical system. Specifically, we analyzed a rotating self-gravitating system under the influence of an external potential well. We focus our interest on the asymptotic situation where the light components has a widespread distribution in space in regard to the heavy component, which could deserve interest the study of star distribution of an elliptical galaxy under the gravitational influence of the associated dark matter halo. As evidenced here, the rotation asymmetry is a very important ingredient to develop a realistic approach of known truncated astrophysical systems such as globular clusters and elliptical galaxies, specifically during the occurrence of gravitational collapse when the effects of anisotropy are very strong.

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Principles of non-equilibrium thermodynamics and the micro-macro coexistence conjecture

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Introduction

Previously, I have emphasized the existence of a remarkable analogy between statistical mechanics and quantum mechanics. This analogy supports the existence of both uncertainty

relations among thermodynamic quantities and general principles for non-equilibrium ther- modynamics. Recently, I have suggested that such principles could be justified in the frame- work of Riemannian reformulation of classical fluctuation theory. Now, I discuss some ideas

and results in advance concerning this problem, such as Micro-Macro Coexistence (MMC)

conjecture and the possible thermo-statistical counterparts of some known equations of mi- crophysics. In particular, the MMC conjecture asserts that the laws of microphysics and

macrophysics are just complementary and fundamental views of a certain unified statisti- cal theory. Apparently, this hypothesis is required to guarantee the internal mathematical

self-consistence of laws for non-equilibrium thermodynamics. It seems to suggest a different

solution to the arrow of time paradox: the irreversibility observed in Nature as an intrinsic fea- ture of physical realm instead of an effective property resulting from our incomplete knowledge

about the reversible microscopic phenomena. Besides, the MMC conjecture involves ideas like bidirectional emergence, complex nature of time, Einstein-Bohr correspondence principle, the complementary character of first and second principles of thermodynamics, the quantification of entropy production, among others.

Acknowledgment

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Quantum approach to the second law of thermodynamics

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Introduction

In this work, we are going to show some entropic properties of dy- namical quantum semigroups that allow writing the quantum version

of the second law of thermodynamics. We are also going to show the

time evolution of some particular quantum dynamical maps with prop- erties that are in clear contradiction with the standard formulation of

classical second law.

Predictive Statistical Mechanics: Jaynes's vision and a new foundation

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Introduction

In the 50s and 60s, Edwin T. Jaynes proposed a conceptual extension of Gibbs's statistical mechanics, then named as predictive statistical mechanics, and known today as the principle of maximum entropy (MaxEnt), strongly supported in the Bayesian interpretation of probability. In this extension, statistical mechanics is seen as the methodology to construct the less biased predictive models using incomplete information, provided by external restrictions to the system. In the vision of Jaynes, later refined by other authors, the Gibbs-Shannon-Jaynes entropy is the key piece that allows choosing the best distribution among a set of candidates compatible with the restrictions imposed.

In this presentation we will review elements commonly understood as Bayesian probability and the principle of maximum entropy from an alternative fundamental point of view, which considers the idea of estimation as the basis of inference, and dispenses with the idea of entropy and its maximization. This vision provides us with additional tools that could complement the exploration of the meaning of information and probability.

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Cosmic-rays transport within Milky Way

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Introduction

Galactic Cosmic-rays (CR) are populations of charged particles produced due to Milky Way39;s activity. The CR observed fluxes at Earth allow us to extract information on source composition and underneath physical processes. The CR transport in the Milky Way's region is usually modeled as a diffusion equation due to the effect on CR from turbulent magnetic fields. In this talk, we present some state-of-art descriptions of the modeling and solution of the transport equation.

Understanding graphene and graphitic ZnO and ZnS nanofilms: A computational approach

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Introduction

Thin films often have structures and properties which differ substantially from those of the bulk. Enormous effort is for example being paid to non-carbon graphene- like two-dimensional nanomaterials. Here periodic density functional calculations are carried out to analyze the structures and energy landscapes of non-polar and polar ZnO and ZnS nanofilms. Thin polar films adopt either an "eclipsed" graphite-like [1] or d-BCT (body-centered tetragonal) structure [2-3], which are very different from the wurtzite (WZ) or zinc blende (ZB) structures adopted by the bulk systems. We also demonstrate the formation of a metastable "staggered" graphitic-like structure, and possible kinetic pathways for transitions from the graphitic forms are examined by explicit evaluation of transition state energies.

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Importance of theoretical and applied research in statistical physics with a focus on industry

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Introduction

This work shows the current importance of theoretical and applied research in statistical physics, giving as a example the relationship of this branch of physics with three key hot topics in today's industry, such as Machine Learning (ML), Data Science (DS) and Artificial Intelligence (AI). The current technological development of the industry (financial, retail, mining, hotel, transportation, among others[1]) allows that the creation of digital and/or technological solutions is not an impediment to achieve competitive products and services. From this perspective, concentrating the investment in creating digital solutions does not help to differentiate one brand or service from another, for this reason it becomes essential to analyze and understand the information obtained, even managing to predict it by modeling. Then, using different tools and statistical tests on the information, it's possible to deliver a personalized and effective service as well as to perform controlled and efficient processes. The applications associated with the exploitation of the information obtained converge to three key pillars in modern industry, these are ML, DS and IA, which in a fundamental representation correspond to methodologies, models and algorithms developed in Statistical Physics. This talk provides a contingent perspective of the applications and theoretical developments of statistical physics, giving as an example potential applications of ML, DS and AI in the industry.

Examples

Data Science: Predictive models and text mining. Machine Learning: Categorize and learn based on information (Updatable models). Artificial Intelligence: Self-managed tools and new ways of defining business strategy.

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Nonlinear Reaction-Diffusion equation: A quantitative approach to the social outbreak in Chile 2019

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Introduction

For a family of nonlinear reaction-diffusion equations, which typically appear in nonlinear problems, we propose a proper analytical solution based on a power-law ansatz. This kind of ansatz allows us obtaining a set of ordinary coupled equations that are easily solved to build the analytical suitable solution. We apply to the problem that has recently emerged in the Chilean social outbreak associated with statistical indicators of national development and progress, to understand the mean standard of Living connected to the dissatisfaction level of Chilean people. We describe the dynamics in terms of the Verhulst equation using the income distribution, the evolution of the mean incomes and the gross domestic product (GDP). We show that the evolution of the GDP needs to be congruent with the evolution of the mean incomes and that the modification of the distribution shape is crucial to improve the standard living. We hope the present result can positively exert an influence upon the political governance of the country.

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Characterization of written language using quantitative measures of word structuring

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Introduction

Complexity appears naturally in many fields, and the importance of its analysis and development is crucial in promoting a better understanding in both its reach and applications. Take for instance, written language, which is the representation of spoken language by means of a symbolic or text system, we observe repetitive patterns in word formation, prefixes, and suffixes. Yet, syntax and correctness of sentences have large consequences in transmitting the message properly and adequately. The content and meaningful information are remarkably hidden within the pattern construct; simply put, in terms of words combination. It was first observed by Zipf[1] that frequency of repetition should follow a power law, and consequently discovering a path into the inherent meaning which may have more avenues into the analysing written language and its complexity. We have constructed a simple discrimination scheme based on quantitative measures that arise naturally in most written pieces and from it calculated a frequency using words from books of most traditional Latin-American writers [2] and over political speeches using Chilean's last 30 years' presidential reports annual review.

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Complex systems methods applied to weather time series of Antofagasta, Chile.

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Introduction

It is well-known that one of the characteristics of the atmosphere is its marked non-linear behavior since it is an extremely open system that interacts with both the continental terrain and the oceanic masses, being also conditioned by the cycles of our planet to the local and global level. Currently, these phenomena can be studied, even sometimes interdisciplinarily, through the lens of complex systems; but, What are complex systems? These are defined as those systems composed of a large number of agents that interact with each other, and whose behavior changes both in space and time, giving way to phenomena that traditionally appear in non-linear systems such as long-range correlations and dependence of the initial conditions, but other more peculiar phenomena such as universality, emergence, criticality, self-organization, and scale invariance also appear, to name a few. In this investigation, complex systems tools were applied to time series of data from the weather station of Universidad Católica del Norte, where a part of these phenomena could be observed.

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