Dinámica Solar: Explorando la Topología a través de Series de Tiempo

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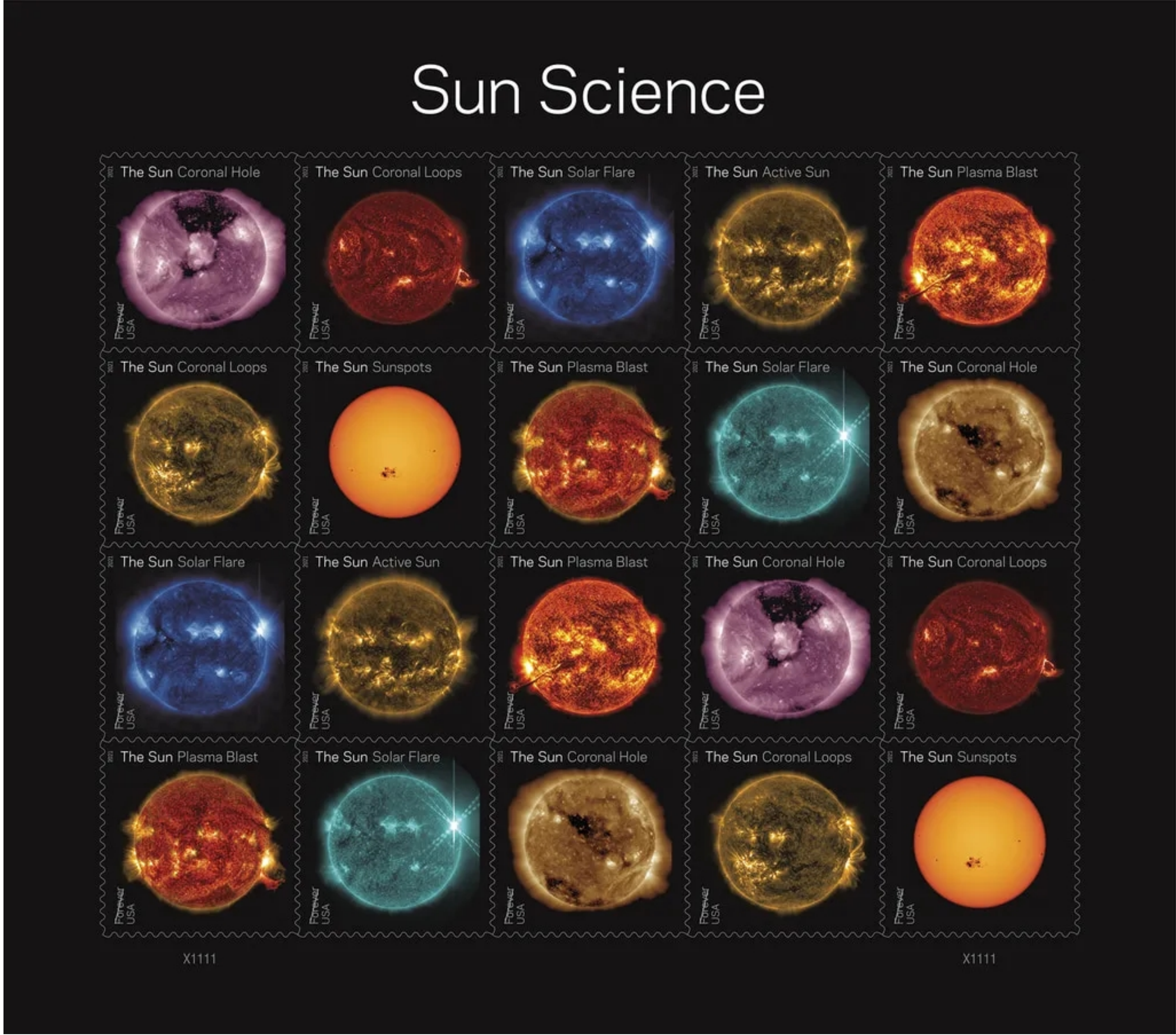
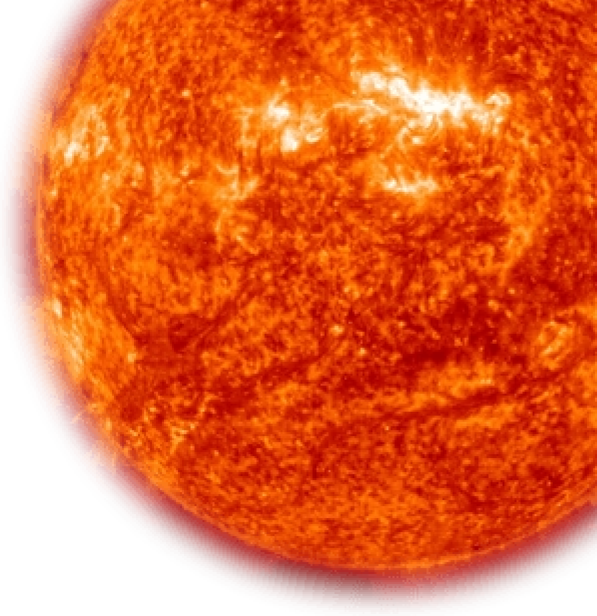


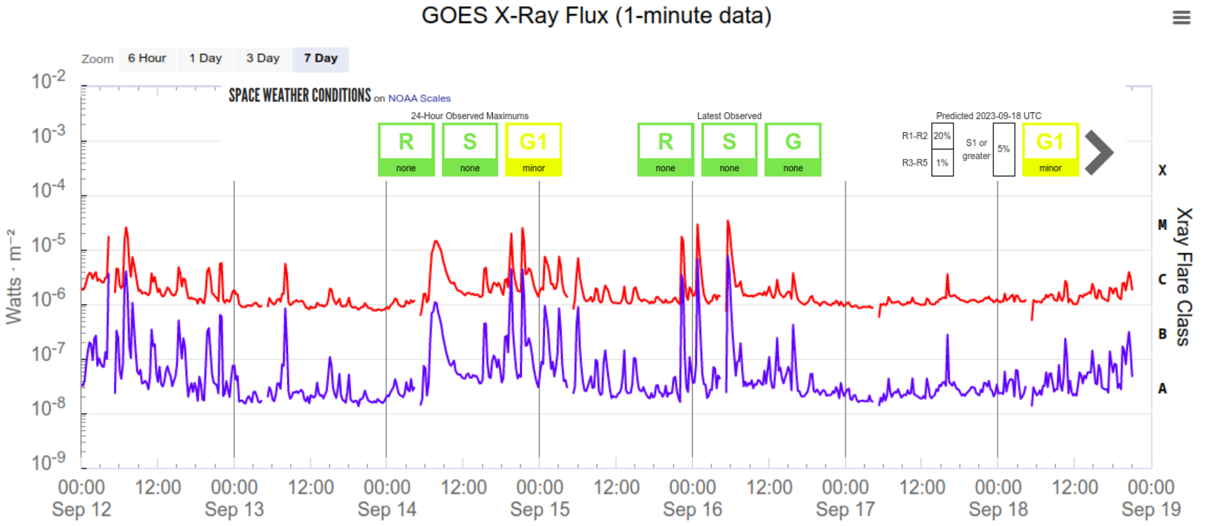
¿En qué(dónde) enmarcamos esta charla?



Clima espacial: ¿Qué es?
Se refiere a los cambios en el ambiente espacial cercano a la Tierra, generalmente producidos por el sol, pero no limitados a éste.

Nuestro Sol:
Energía: 386×10^{12} MW (luz, partículas, campo magnético)
Ciclos: - 27 días (Barlow rotation)
- ~100 días, regiones activas en desarrollo
- ~11 años
- ~22 años
- ~88 años

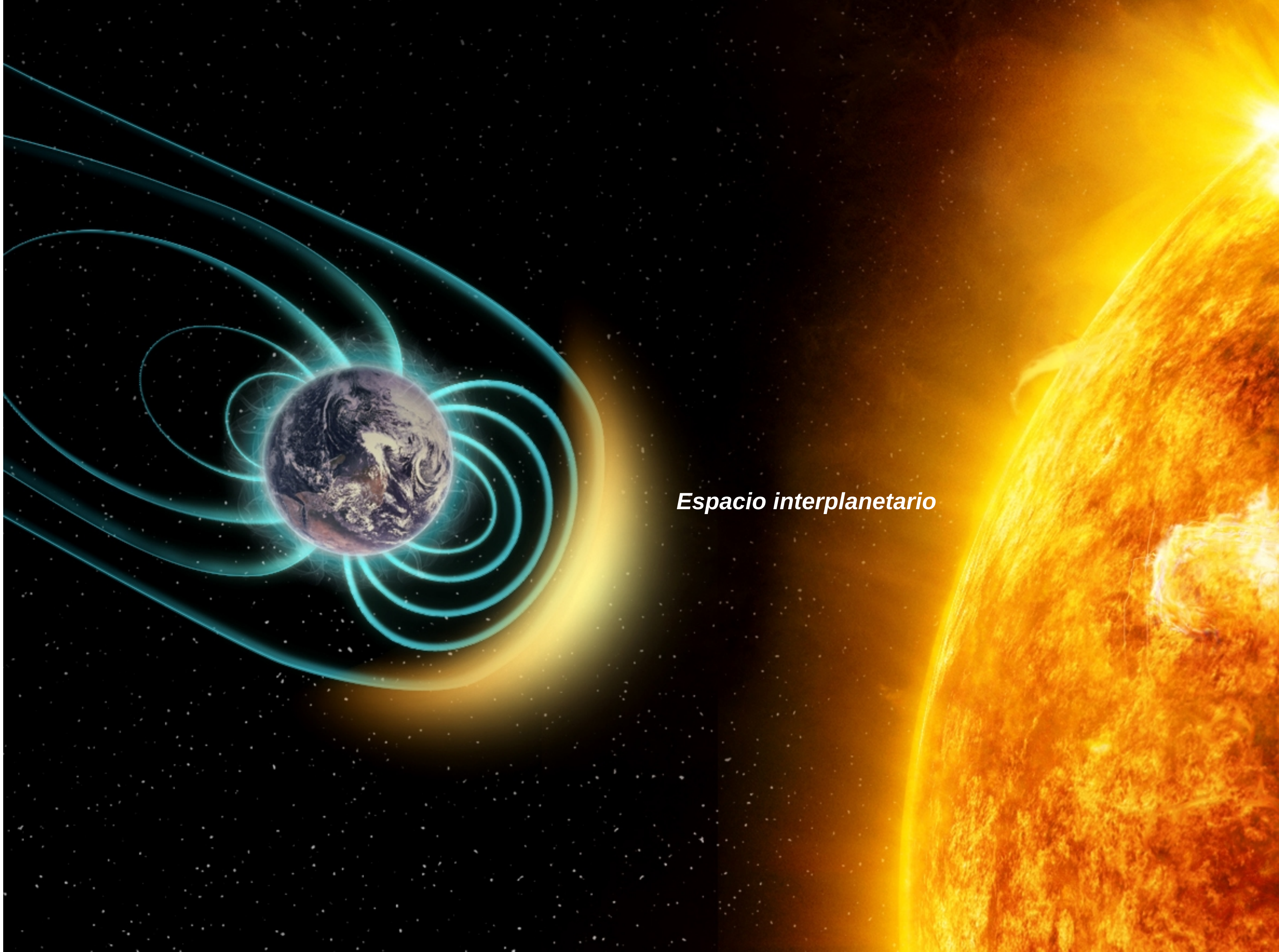
Los eventos usualmente se inician por un erupción solar o una eyección de masa coronal! Incrementos de muchos órdenes de magnitud en pocos minutos.



Espacio interplanetario:

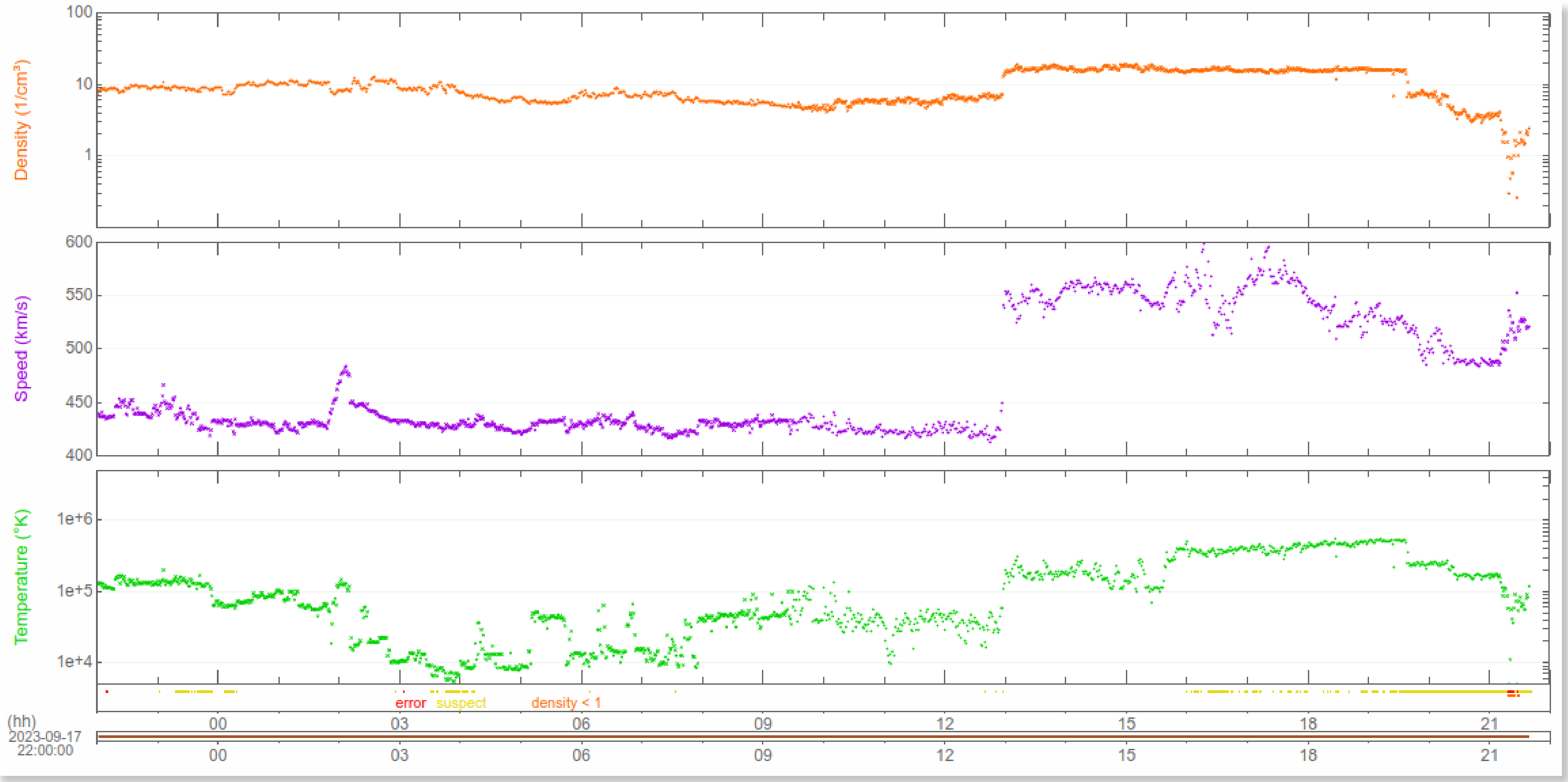
- Viento solar
  - Flujo saliente constante desde el sol
  - Electrones y protones

- Distorsiones desde el Sol produducen ondas y choques en el viento solar



El viento solar:

- **Densidad**: 1 a 100 partículas por cm3
- **Velocidad**: 200 a 800 km/sec
- **Temperatura**: Aquí hay un pequeño problema!…. (miles a millones de Kelvin)

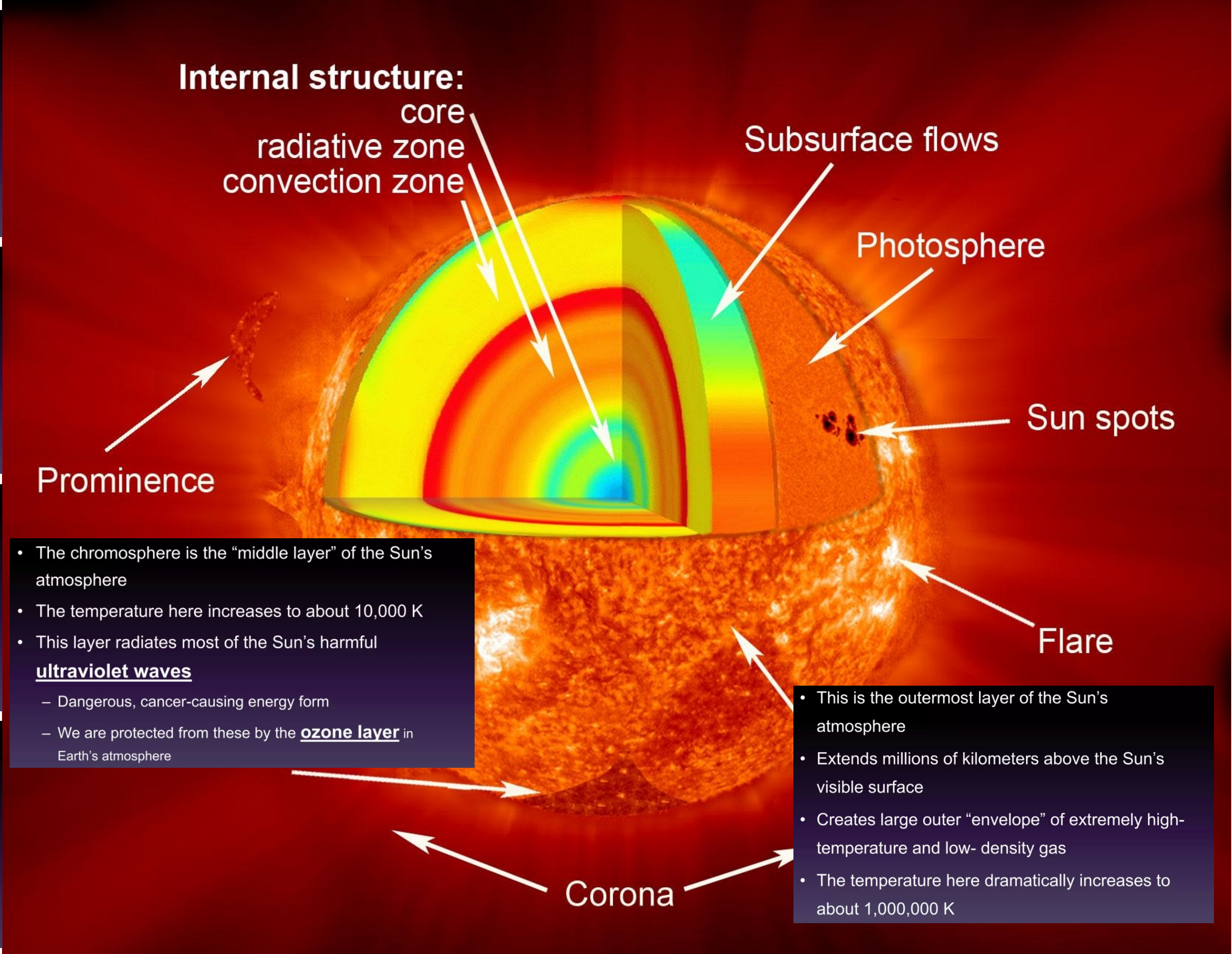


- The **core** is the source of the Sun's energy.
- Energy is created through a process called **Nuclear Fusion:**
  - Atoms can travel so fast that when they collide, they "fuse" together and release energy
  - Hydrogen atoms within the Sun fuse to form Helium and release energy we receive as heat and light
- Temperature: 15,000,000 K

- Here, energy moves up and out from the core traveling as **photons**
  - Photons are physical "packets" of energy
- The temperature here is cooler than the core: about 10,000,000 K.

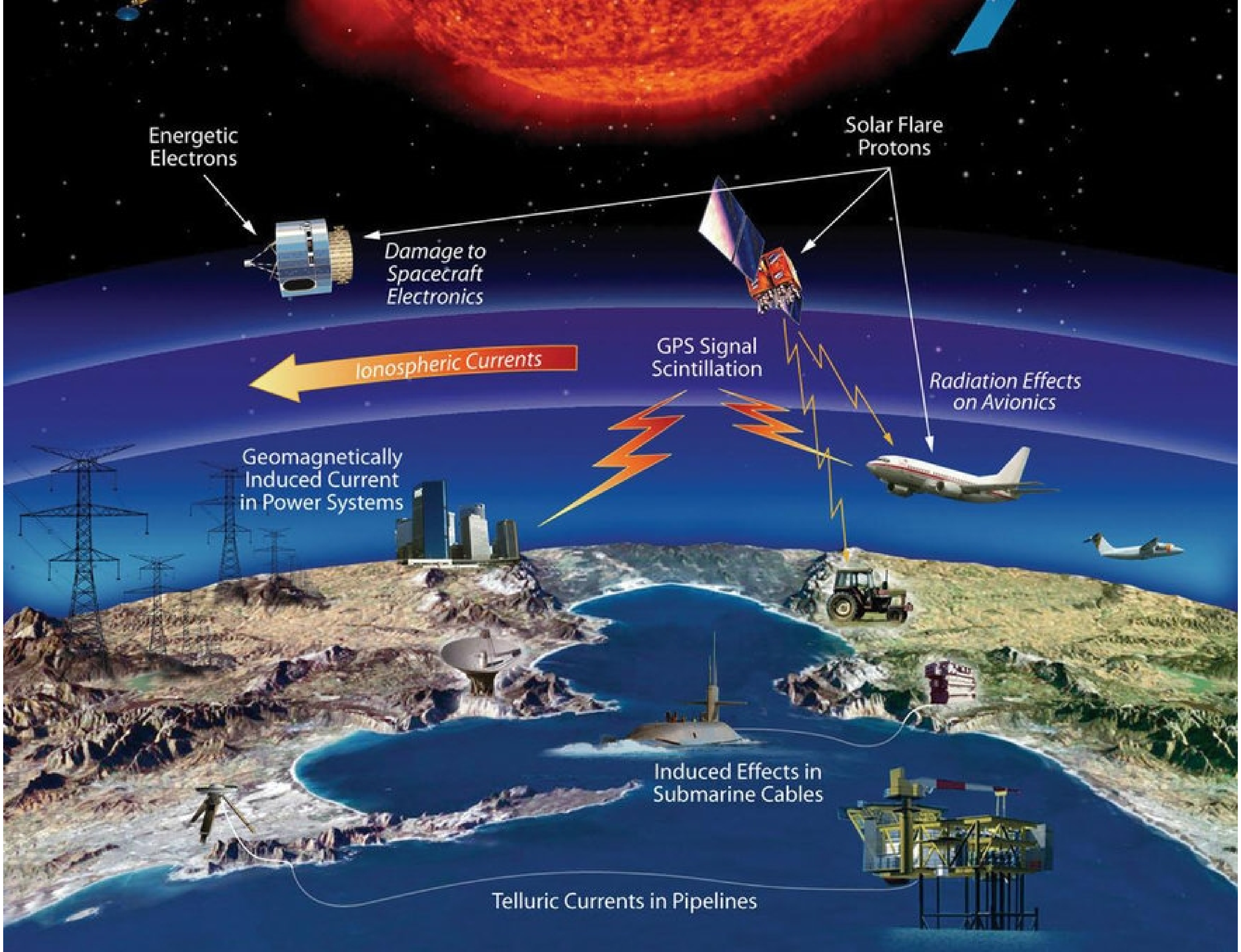
- **Convection** is a process in which warmer, less dense matter rises, and cooler, more dense matter sinks.
- As a result of convection, the energy in this layer moves up with warmer plasma and sinks with cooler plasma.
- Cools down to 5,000,000 K in this layer

- The **photosphere** is the visible surface of the Sun.
- This surface turns and churns like a pot of rapidly boiling water.
- This layer has **sunspots**
  - Parts of the Sun's surface get interrupted by intense magnetic fields and appear as blackened spots in camera images of the Sun
- Temperature in this first layer of the Sun's atmosphere dramatically decreases to about 6000 K



- The chromosphere is the "middle layer" of the Sun's atmosphere
- The temperature here increases to about 10,000 K
- This layer radiates most of the Sun's harmful **ultraviolet waves**
  - Dangerous, cancer-causing energy form
  - We are protected from these by the **ozone layer** in Earth's atmosphere

- This is the outermost layer of the Sun's atmosphere
- Extends millions of kilometers above the Sun's visible surface
- Creates large outer "envelope" of extremely high-temperature and low- density gas
- The temperature here dramatically increases to about 1,000,000 K



¿Cómo nos afecta esto?

Relationship between magnetic rigidity cutoff and stochastic behavior in cosmic ray time series

Relationship between magnetic rigidity cutoff and stochastic behavior in cosmic ray time series using visibility graph and network analysis techniques

AIP Publishing | Chaos An Interdisciplinary Journal of Nonlinear Science

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In Review

(Dated: 11 July 2023)

Cosmic rays are highly energetic particles originating from astrophysical events outside the Solar System. In this study, we analyze the time series of cosmic ray flux measured by neutron detectors at 16 monitoring stations distributed worldwide. By applying visibility graph analysis, we explore the relationship between the magnetic rigidity cutoff (R_c) and the multifractality and topology of the cosmic ray time series. Our results reveal a significant association between the magnetic rigidity cutoff and the multifractality of the cosmic ray time series. Specifically, the analysis of visibility graphs and network properties demonstrates that the magnetic rigidity is inversely related to the magnetic rigidity cutoff. The identified relationship between magnetic rigidity and fractality provides insights into the chaotic nature of cosmic ray variations and their potential uses for predictability.

Cosmic rays, which are highly energetic particles originating from astrophysical events beyond our Solar System, have captivated scientists for many years due to their fascinating properties and their impact on the space environment. In this investigation, a novel approach based on visibility graph analysis was employed to explore the correlation between the multifractality of cosmic ray time series and the magnetic rigidity cutoff. The primary objective was to gain a deeper understanding of the chaotic dynamics exhibited by these variations and their potential for prediction. The outcomes unveiled a noteworthy connection between the magnetic rigidity cutoff and the multifractality of cosmic ray time series, shedding further light on the intricate nature of this phenomenon and its relationship with the structure of the detector network. These findings not only contribute significantly to the field of astrophysics but also hold valuable implications for comprehending solar activity patterns and forecasting cosmic events. As humanity advances in space exploration and our understanding of astrophysical phenomena, thi… assumes a pivotal role in enhancing our knowledge… mic rays and their behavior within our vast cosm… ronment.

On the surface of the Earth, neutron detectors continually gauge the intensity of cosmic rays[4,5]. These detectors measure the frequency of collisions involving neutrons and atmospheric particles, rendering them highly responsive to cosmic ray fluctuations. Consequently, neutron detectors serve as valuable tools for investigating geophysical and climatic variations. Their continuous monitoring has yielded significant findings, including the identification of links between solar activity[6–8] and terrestrial temperature[9–11].

The study published at[12] but also in[13] has used the multifractal detrended fluctuation analysis (MFDFA)[14] technique to investigate the relationship between geomagnetic rigidity cutoff (R_c of neutron stations) and multifractal variability and behavior in the time series of the cosmic ray flux on Earth. The data used for the study were collected from 32 neutron monitoring stations distributed around the world with rigidity cutoff in the [0.0,15] GV interval. The objective is to determine the intrinsic relationship of the multifractality measure for the cosmic ray time series with the rigidity cutoff of each

Characterizing Solar Activity through Network Analysis and Fractal Patterns in Solar Wind Classification Data

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In Preparation

Abstract

In this research, we apply Horizontal Visibility Graph Analysis (HVGA) to explore and uncover hidden patterns in solar wind data, providing valuable insights into solar activity. The HVGA technique involves transforming time series data into complex networks, enabling us to study the relationships and interconnections among different solar wind events. Our dataset consists of four distinct types of solar wind events, including ejecta, coronal hole origin plasma, streamer belt … ind event, … stribution, … solar wind … centrality, … eters offer … tivity and … to identify … on of shuf… … om effects.

International Statistical Review
Discussion

In Review

Exploring Chaotic Dynamics and Unpredictability of Time Series through Visibility Graph Analysis: A Case Study on Dengue Incidence

Submission Status	Under Review
Manuscript ID	ISR-DSR-096-23
Submitted On	11 August 2023 by David Porta
Submission Started	11 August 2023 by System

This submission is under consideration and cannot be edited. Further instructions will be emailed to you from ScholarOne.

Submission overview →

em Chaos, Solitons and Fractals: the interdisciplinary journal of Nonlinear Science, and Nonequilibrium and Complex Phenomena

David Sierra Porta

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In Review

Submissions Being Processed for Author

Page: 1 of 1 (1 total submissions)

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Action		Manuscript Number	Title	Initial Date Submitted	Status Date	Current Status
Action Links		CHAOS-D-23-03167	A multifractal approach to understanding Forbush Decrease events: correlations with geomagnetic storms and space weather phenomena	Jun 24, 2023	Sep 17, 2023	Under Review

Sun dynamics from topological features

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ARTICLE INFO

Keywords:
Sun's dynamics
Spectral features
Image processing
Space weather

In Review

ABSTRACT

The present study presents an extensive dataset meticulously curat
from the Solar and Heliospheric Observatory (SOHO), encompass
This collaborative effort spans multiple disciplines and culminat
methodology that traverses the entire spectrum from solar imaging
parameters and relevant characteristics.

The significance of this undertaking lies in the profound ins
Encompassing diverse spectral bands and employing topological
the multifaceted dynamics of solar activity, fostering interdisciplin
with other solar phenomena. Consequently, the data's intrinsic
affording researchers in solar physics, space climatology, and relat
intricate processes.

To achieve this, an open-source Python library script has be
three pivotal stages: image acquisition, image processing, and para
conceived as discrete modules, these steps have been unified into a
entire process. Applying this script to various solar image types ha
subsequently synthesized into a comprehensive compilation throu

During the image processing phase, conventional libraries like
analysis tools were harnessed to refine images for analysis. In contr
established URL libraries in Python, facilitating direct access t
images and eliminating the need for local storage.

The computation of spectral parameters involved a fusion of s
tailored algorithms for specific attributes. This approach ensures precise computation of a diverse
array of attributes crucial for comprehensive analysis of solar images.

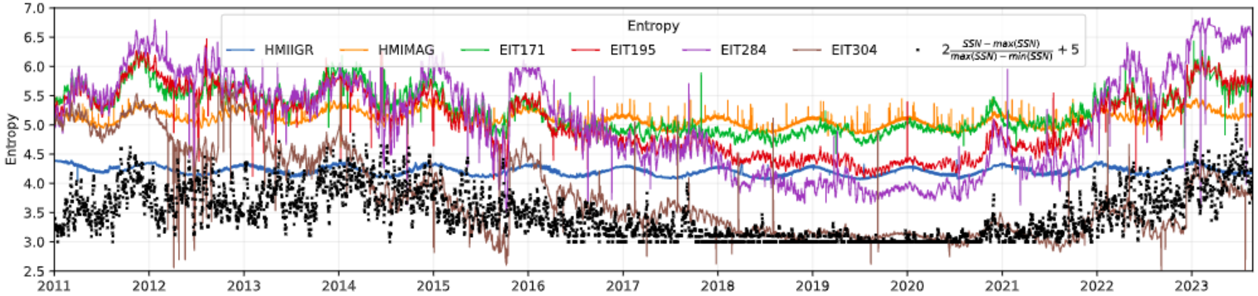

Figure 2: Entropy variations observed across different filtered image series obtained from diverse filters. The x-axis represents the chronological progression of time, while the y-axis displays the entropy values. Each line on the graph corresponds to a distinct filter, revealing the dynamic changes in image complexity over time.

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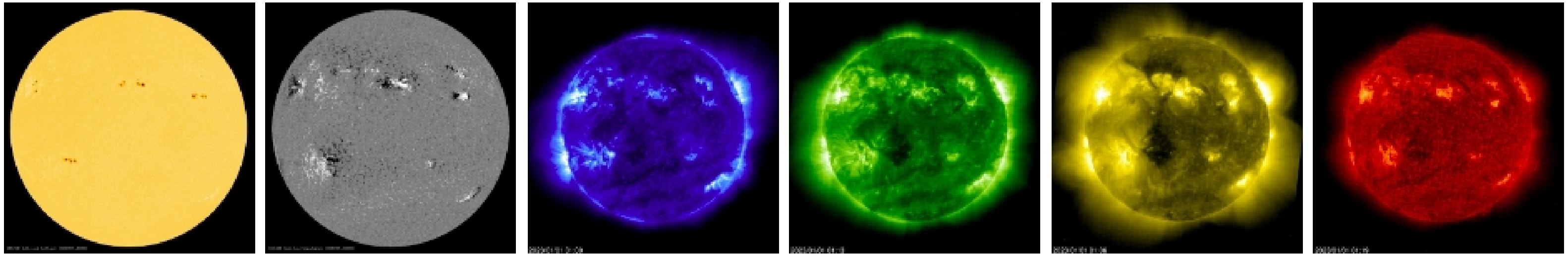

Figure 1: Images used for the construction of the results. All images are for day 20230101 and are presented in order from left to right HMIIGR and HMIMAG (Helioseismic and Magnetic Imager Intensitygram) in the electromagnetic spectrum range of the visible region and part of the near-infrared spectrum, respectively, and EIT171, EIT195, EIT284 and EIT304 (Extreme Ultraviolet Imaging Telescope 304) in the extreme ultraviolet region, for 171, 195, 284 and 304 angstroms, respectively.

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Published

Quantitatively relating cosmic rays intensities from solar activity parameters based on structural equation modeling

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Available online 6 March 2023

Abstract

Cosmic rays measured through neutron monitors on Earth's surface have a strong correlation with t
solar photosphere. Other indices that affect the dynamics of the heliosphere and distortions in the Earth's
significant correlations. Typically, studies focus on these indices individually or combine some into a small
uses Structural Equation Modeling to examine relationships between a broad range of parameters of s
intensity (measured by the Moscow neutron monitor) across several solar cycles from 1976 to present day.
indices into three distinct contributions: Photosphere, Solar Wind and Terrestrial Geomagnetic Field D
were built for all solar cycles and the complete cosmic ray series from 1976 to the present, resulting in g
p-values below 0.05 (95% confidence). Relationships among all contributions were determined using thei

Keywords: Cosmic rays; Sun dynamics; Modelling; Heliospheric Abundances; Photosphere; Solar wind

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https://doi.org/10.1007/s10509-022-04151-5

RESEARCH

On the fractal properties of cosmic rays and Sun dynamics cross-correlations

D. Sierra-Porta[1]

Published

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ate the cosmic rays and ten physical parameters of heliosphere behavior considering the scaling features of their
olution. Our analysis start with the cosmic rays measurements by a neutron monitor station located in Moscow, as
t, Ap index, Na/Np, Alfven mach number, DST index, Kp index, Plasma beta (β), Proton temperature, $F_{10.7}$ index
agnitude $|B|$ (Interplanetary Magnetic Field, IMF), for the period 1976 to early 2020. Each of these datasets was
using the Multifractal Detrended Fluctuation Analysis and Multifractal Detrended Cross-Correlation Analysis in
estigate intrinsic properties, like self-similarity and the spectrum of singularities. The main result obtained is that
rays time series as well the 10 heliospheric parameters exhibit positive long-range correlations with multifractal

Topological statistical methods · Cosmic rays · Sun dynamics · Heliospheric physics

uction

and from all directions our Earth is continuously
a type of radiation that we collectively call Cos-

from the sun, or produced as a result of the collisions of pro-
tons from outer space with the atmosphere, has been of cru-
cial importance in understanding the mechanisms of energy
generation in the interior of stars.

ELSEVIER
Physica A: Statistical Mechanics and its Applications
Volume 607, 1 December 2022, 128159

Linking cosmic ray intensities to cutoff rigidity through multifractal detrented fluctuation analysis

D. Sierra-Porta, Andy-Rafael Domínguez-Monterroza

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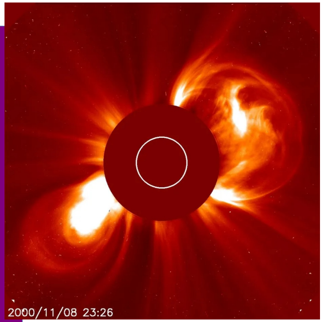
Abstract

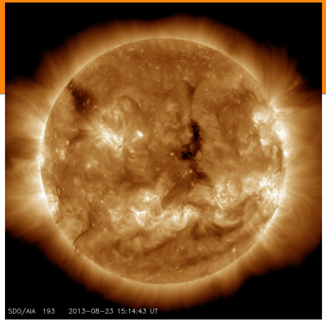
We use multifractal detrented fluctuation analysis (MFDFA) to investigate the relationship between magnetic rigidity or "cutoff rigidity" and the variability and multifractal behavior in the time series of the cosmic ray flux on Earth, which is detected by neutron monitors on the Earth's surface. Because the cutoff rigidity depends strongly on the geographical latitude of the detectors, not all detectors produce equal cosmic ray counts. Our results indicate that there is some bias in the chaotic nature of the cosmic ray series associated with the latitude of the monitoring stations. We obtain an important relationship between the cutoff rigidity (R) for different behaviors and the Hurst exponent of the series corresponding to the counts at the neutron monitor stations. In particular, an inverse relationship is observed with higher rigidity corresponding to a lower Hurst exponent $(H(q=a) = m_a R + B_a)$. In particular, for $q=-10$, considering all time series, the correlation coefficient is approximately 0.80, whereas the R-squared is 0.638, and the coefficients of the linear regression for this case are $m = -0.0425 \pm 0.006$ and $b = 0.8703 \pm 0.025$.

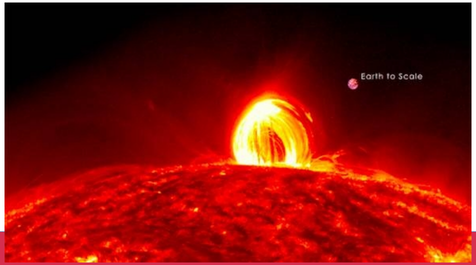
El problema que queremos estudiar...

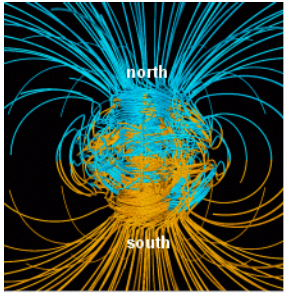
(a) <u>Ejecta</u> (richardson2000sources, zhao2009global): *refers to the most intense and rapid emissions that occur after a coronal mass ejection from the solar corona. Ejecta solar wind is characterized by higher velocity and density compared to other types;*



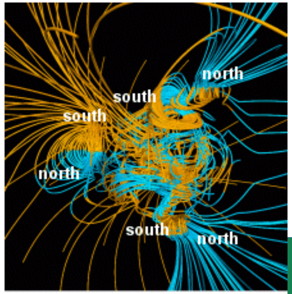
(b) <u>Coronal Hole Origin Plasma</u> (cranmer2009coronal): *this type of solar wind originates from regions of coronal holes where the magnetic field extends into space, and it is characterized by moderate velocity and relatively low density;*







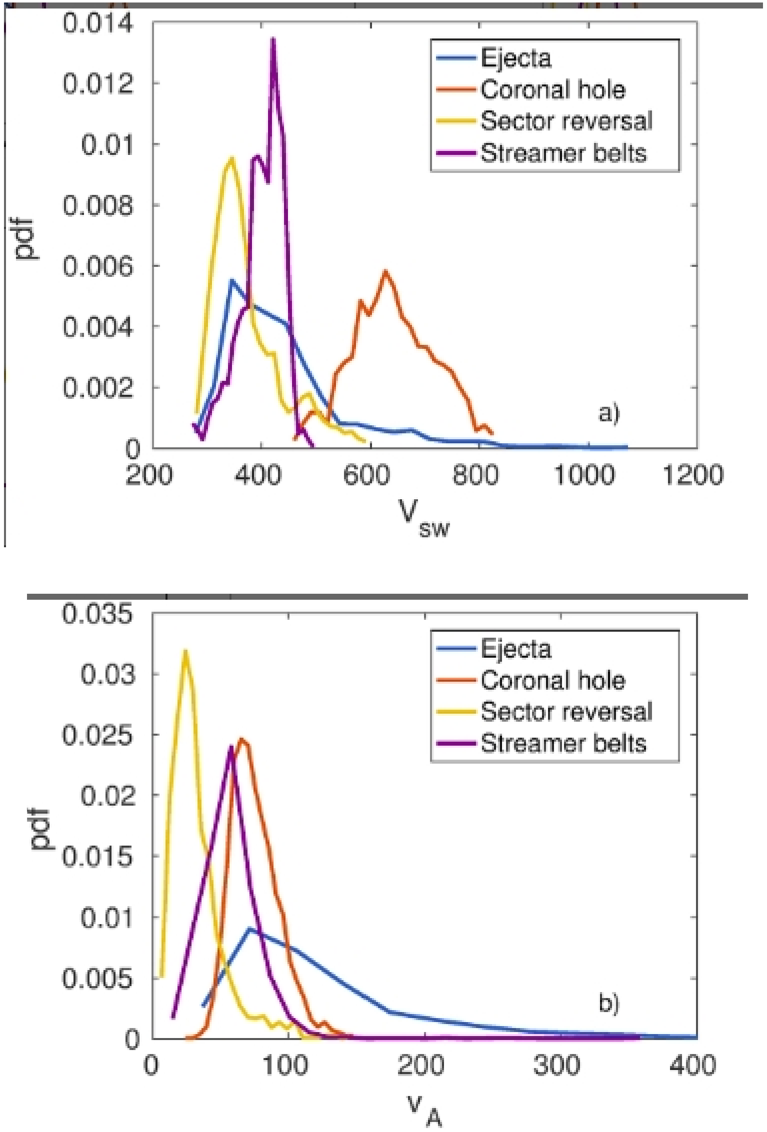
between reversals

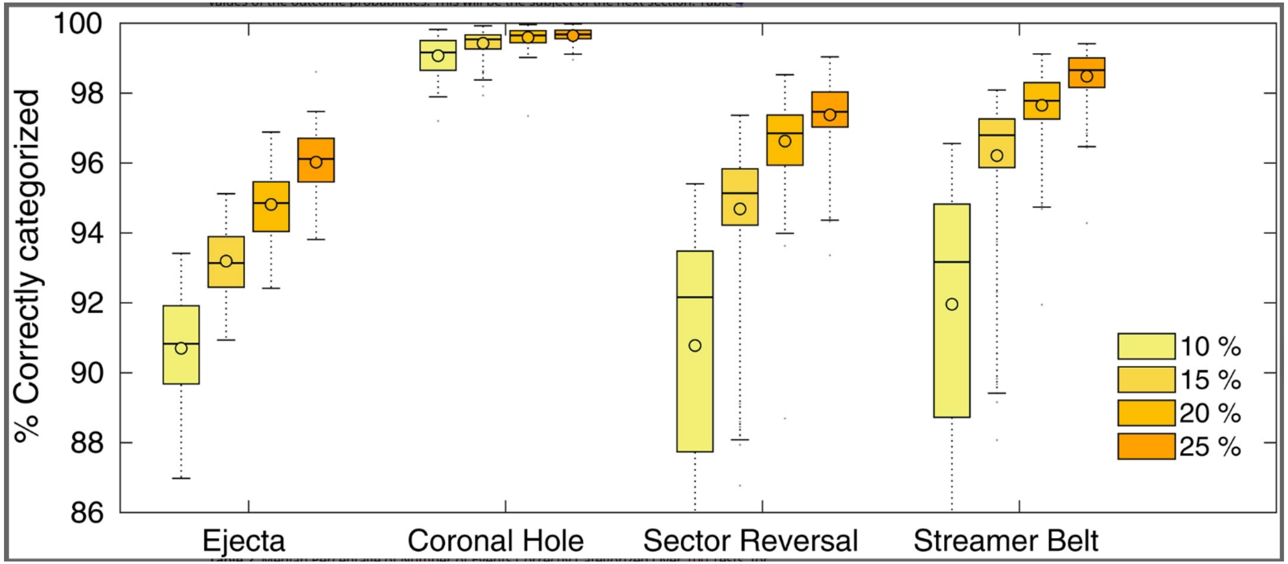


during a reversal

(c) <u>Streamer Belt Origin Plasma</u> (susino2008physical, schwenn2007solar): *solar wind of this type originates from the streamer belt regions, where magnetic field lines twist and form loops, and it has intermediate velocities and densities;*

(d) <u>Sector Reversal Origin Plasma</u> (foulon2009apparent, suess2009quiescent): *this type of solar wind originates in regions where the polarity of the solar magnetic field changes, known as sector reversals, and it exhibits variable velocities and densities.*





All the results of this paper have been obtained with the MATLAB software GPML, available at http://www.gaussianprocess.org/gpml/code (Rasmussen & Nickisch, 2010).

Sistemas Complejos…

Agentes interactúan dando lugar a propiedades emergentes. Los Sistemas Complejos están presentes en diversos campos:

- Mercados Financieros (crisis financieras)
- Epidemias (propagación)
- Sistemas socio-técnicos (difusión en redes sociales, etc.)
- Fútbol (posesión del balón)
- Clima (2021 Nobel Prize in Physics)

The Nobel Prize in Physics 2021

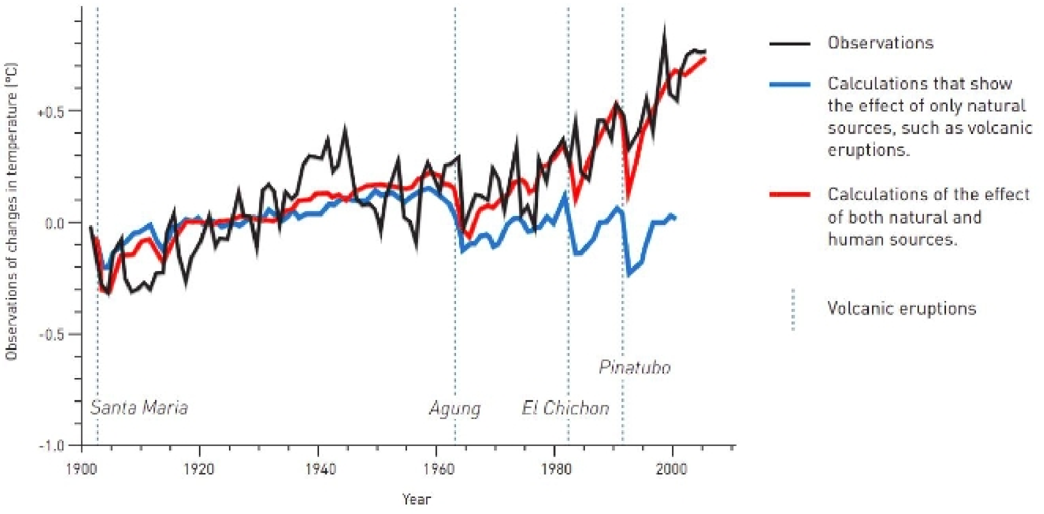
Three Laureates share this year's Nobel Prize in Physics for their studies of complex phenomena. **Syukuro Manabe** and **Klaus Hasselmann** laid the foundation of our knowledge of the Earth's climate and how humanity influences it. **Giorgio Parisi** is rewarded for his revolutionary contributions to the theory of disordered and random phenomena.

They found hidden patterns in the climate and in other complex phenomena

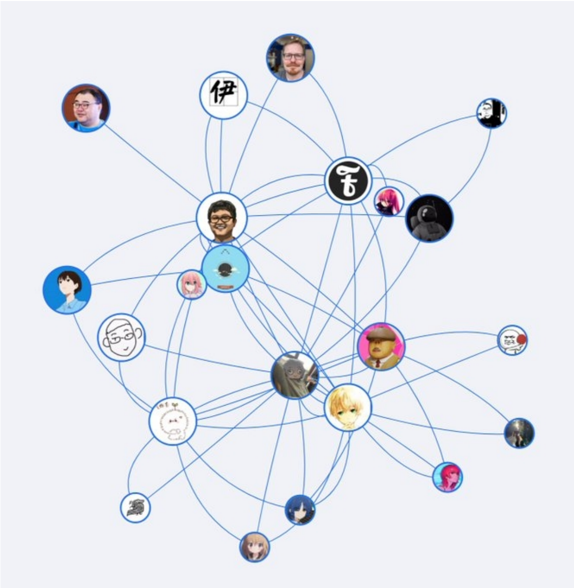
All complex systems consist of many different inter-acting parts. They have been studied by physicists for a couple of centuries, and can be difficult to describe mathematically – they may have an enormous number of components or be governed by chance. They could also be chaotic, like the weather, where small deviations in initial values result in huge differences at a later stage. This year's Laureates have all contributed to us gaining greater knowledge of such systems and their long-term development.

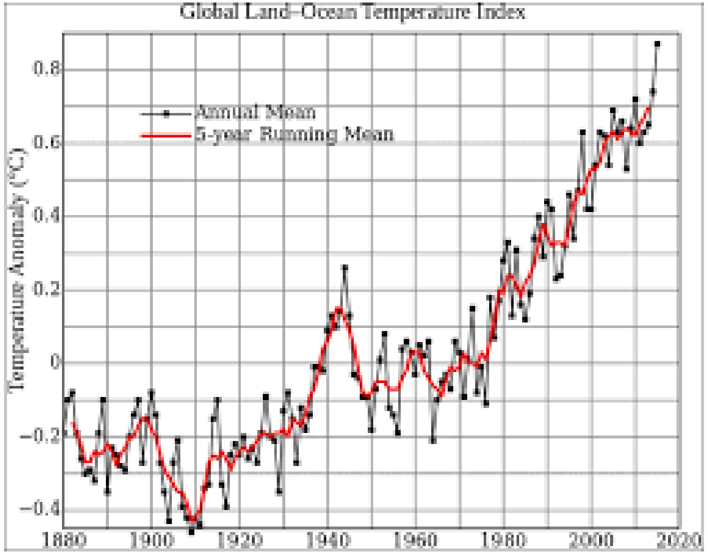
Identifying fingerprints in the climate

Klaus Hasselmann developed methods for distinguishing between natural and human causes (fingerprints) of atmospheric heating. Comparison between changes in the mean temperature in relation to the average for 1901–1950 (°C).



Source: Hegerl and Zweirs (2011) Use of models in detection & attribution of climate change, WIREs Climate Change.





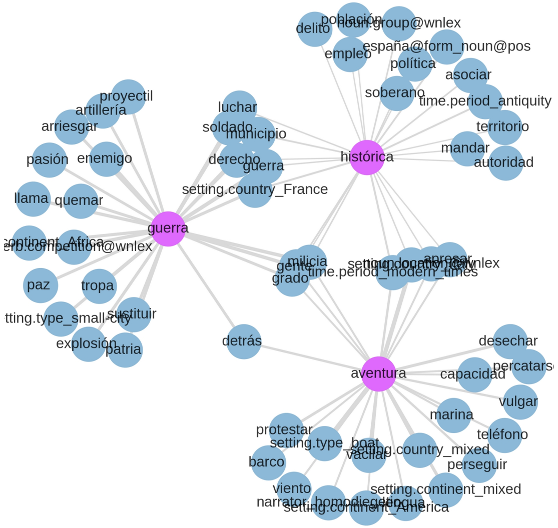
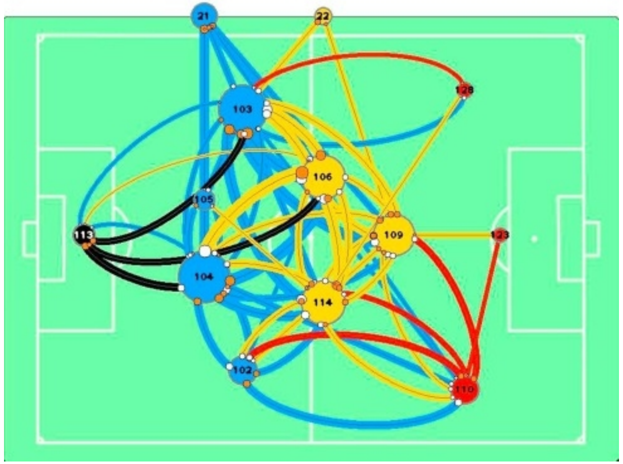
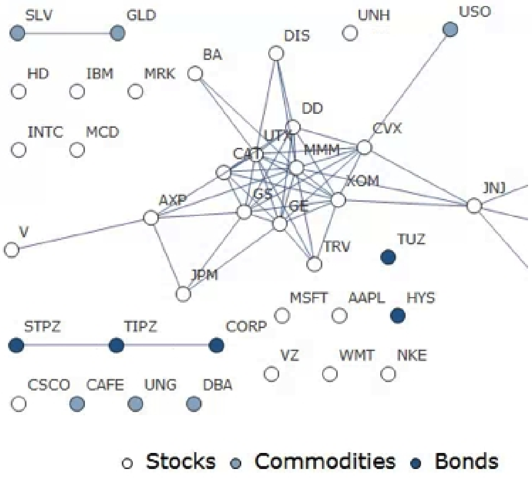
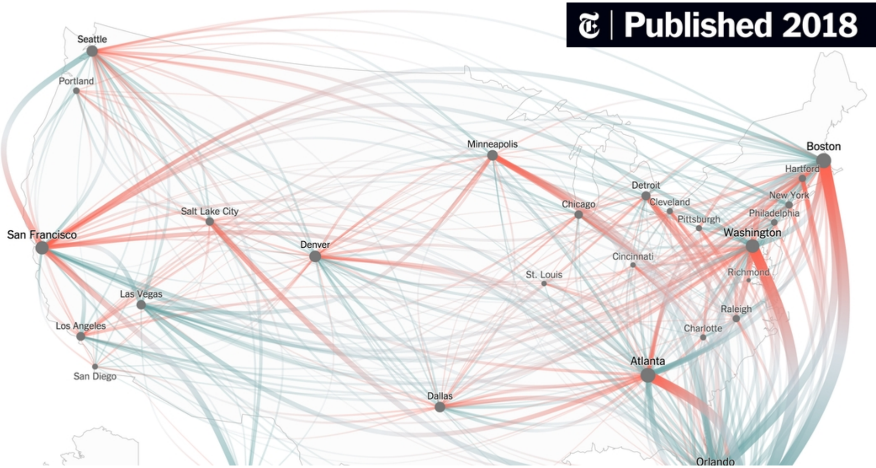


Figure 2: Network of 3 Subgenres and their Distinctive Features Weighted as Z-Scores

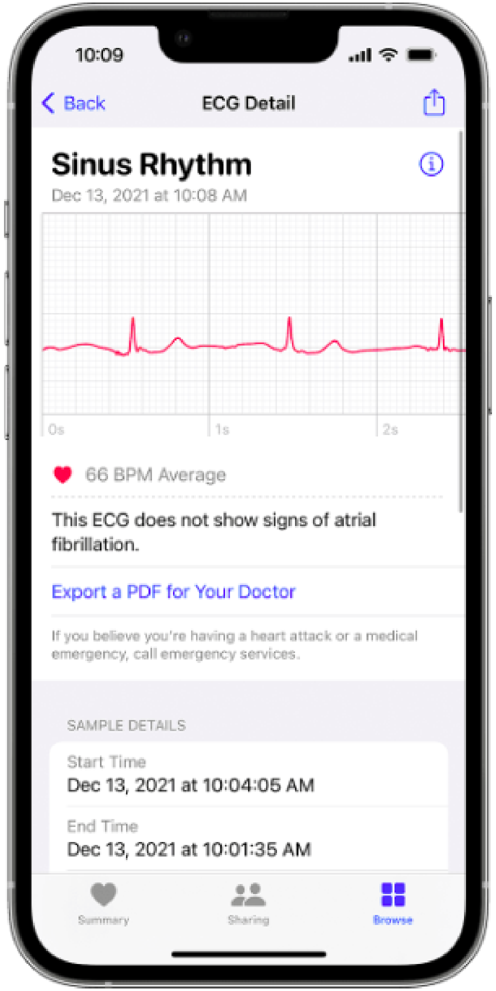






Teoría de Grafos...

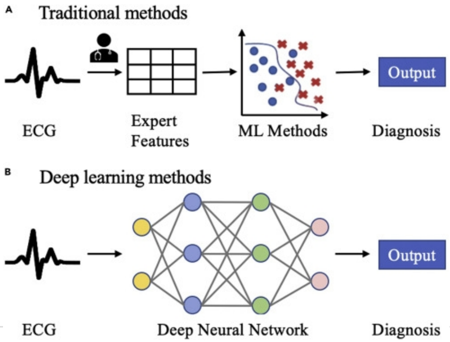
- Una **Red Compleja (grafo)** es una representación realista para estudiar *interacciones* y sus propiedades
- Los grafos al incorporar la **interacción** entre pares de agentes es un modelo más objetivo para estudiar dinámica de diversos sistemas complejos.
- Propiedades de la estructura de la red. Enfoque de estudios sobre redes reales ponen énfasis en **métricas del grafo**: centralidad, comunidades, etc.
- El estudio clásico de **eventos extremos (crisis)** focalizan su estudio en las propiedades estadísticas de los datos. Ej: desestima **interacción**.
- Valorar Riesgo sobre Redes Complejas.

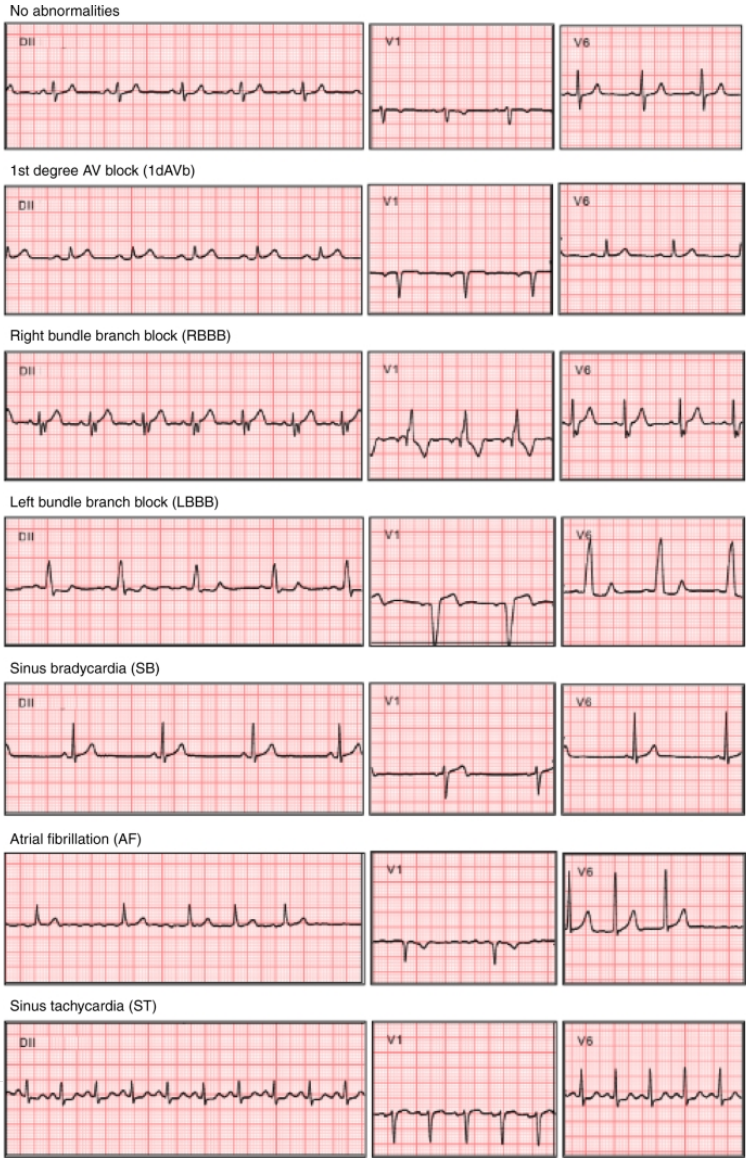


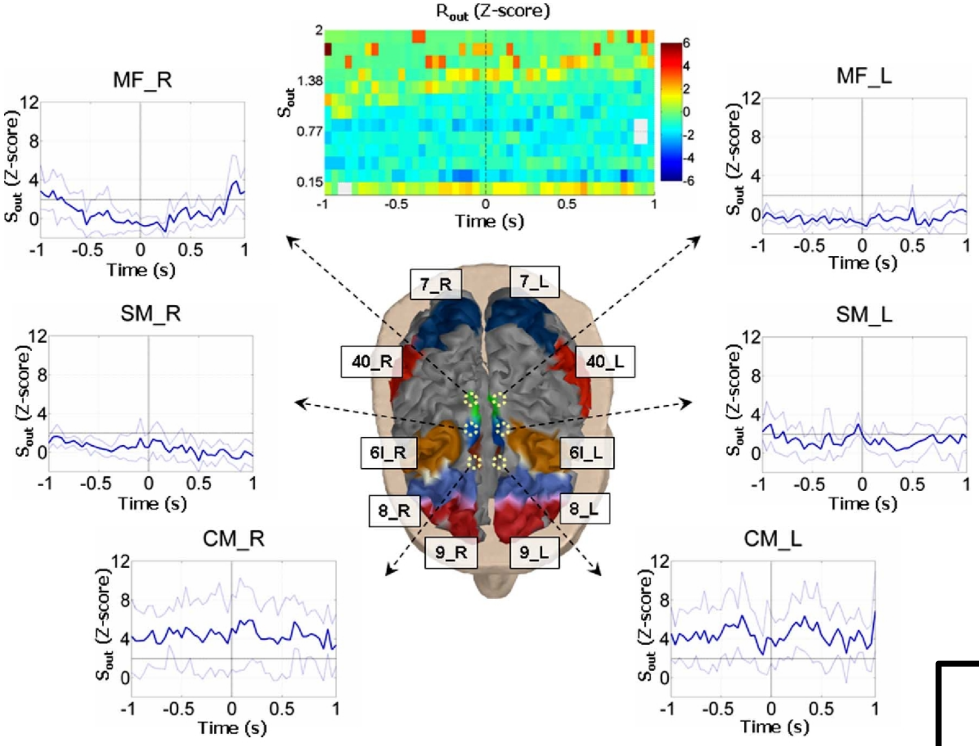
View and share your Health information

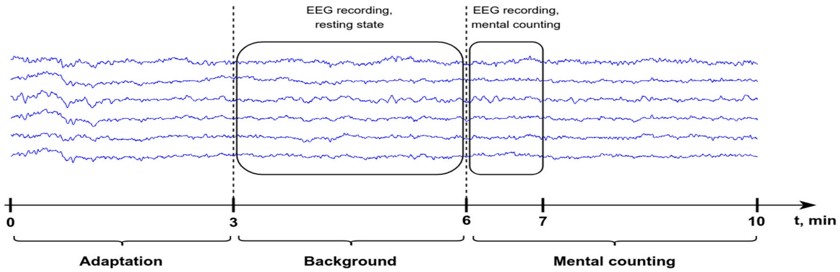
The ECG waveform, its associated classifications, and any noted symptoms will be saved in the Health app on your iPhone. You can also share a PDF with your doctor.

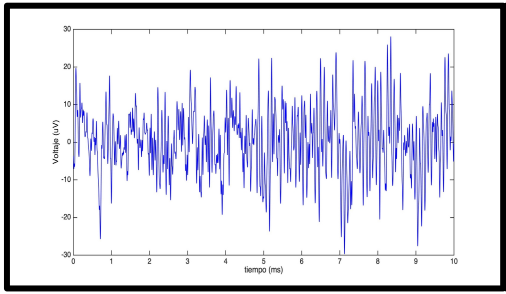
1. Open the Health app.
2. Tap the Browse tab, then tap Heart > Electrocardiograms (ECG).
3. Tap the chart for your ECG result.
4. Tap Export a PDF for Your Doctor.
5. Tap the Share button to print or share the PDF.

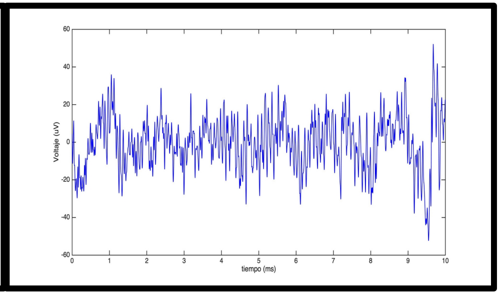






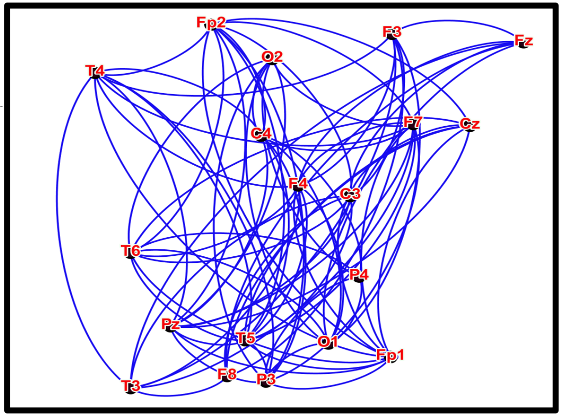


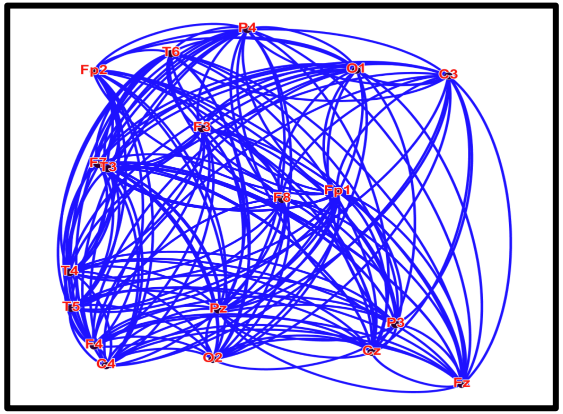




Señal EEG antes de la tarea aritmética (resting) del sujeto identificado como Subject0

Señal EEG durante la tarea aritmética (task) del sujeto identificado como Subject0

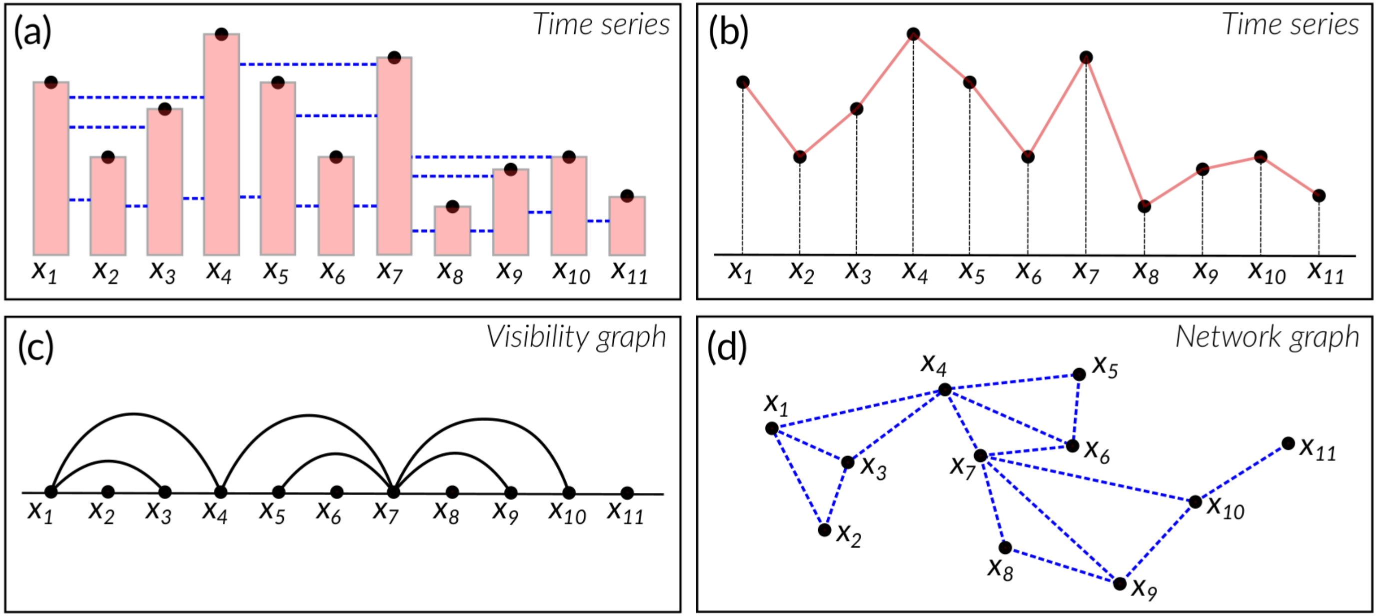




Grafo (no pesado) ***antes*** *de la tarea aritmética sujeto identificado como Subject2*

Grafo (no pesado) ***durante*** *la tarea aritmética sujeto identificado como Subject2*

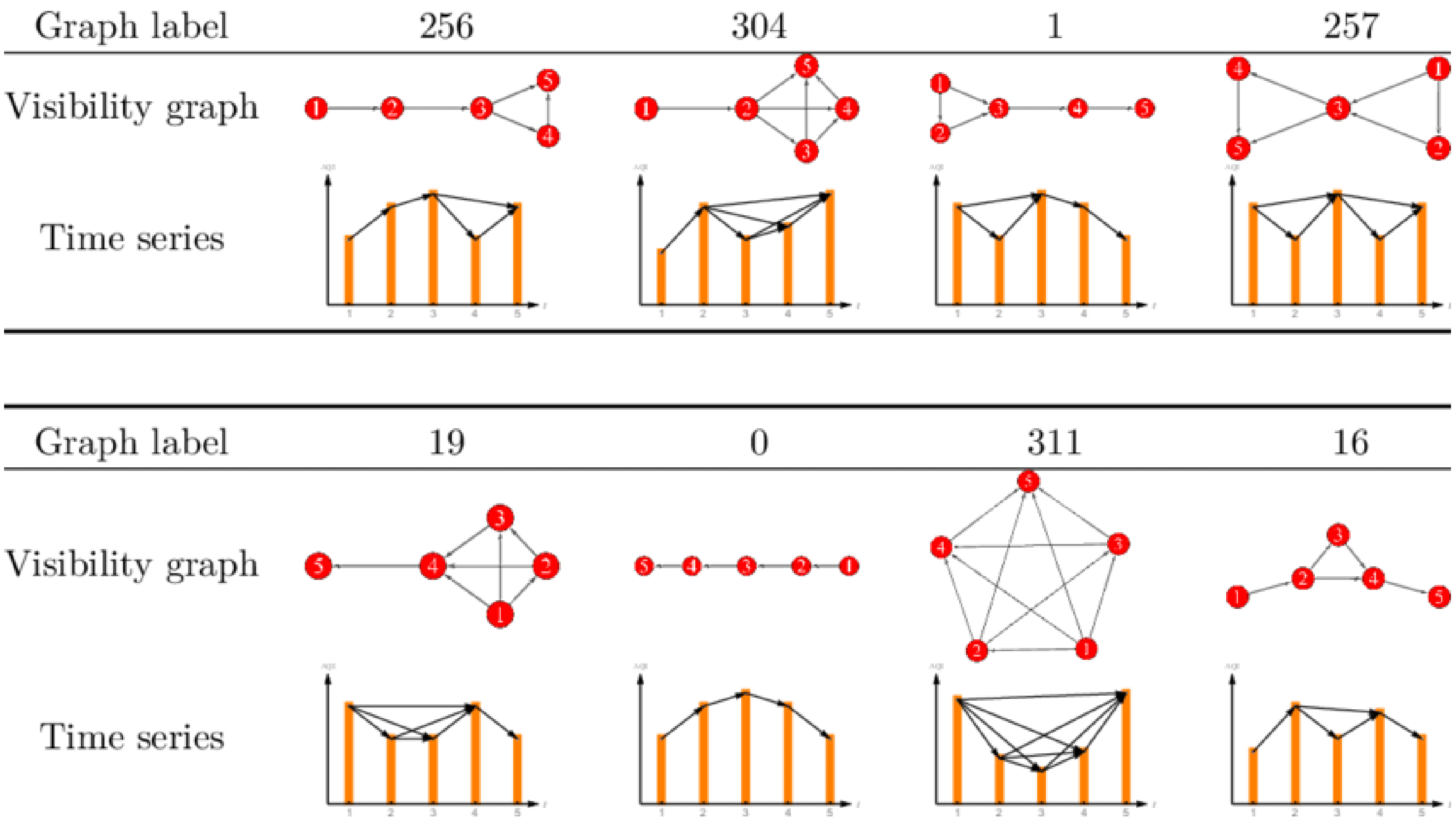
Visibility Graph Analysis...

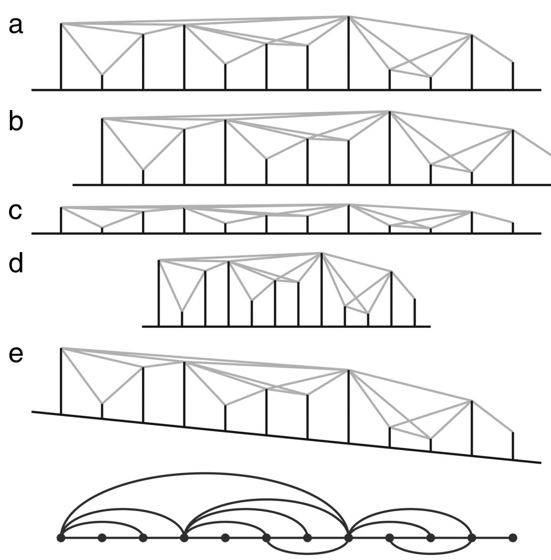


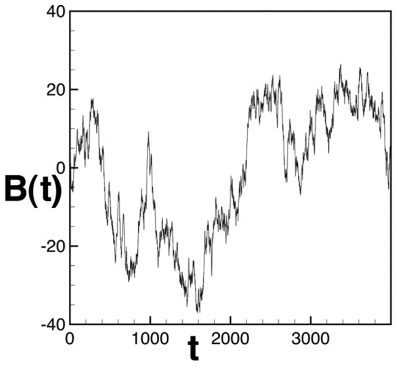
lacasa2008time (also in lacasa2012time) proposed the visibility algorithm as a method to construct complex networks from time series based on the concept of visibility. In this algorithm, each data point (t_i, y_i) is represented as a node in the network, maintaining the same order as in the original time series. Two data points (t_i, y_i) and (t_j, y_j) are connected with an edge if there is visibility between them, which is determined by the condition:

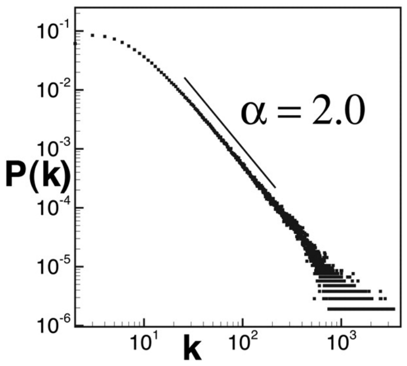
$$y_k < y_j + \frac{(y_i - y_j)(t_j - t_k)}{(t_j - t_i)}.$$

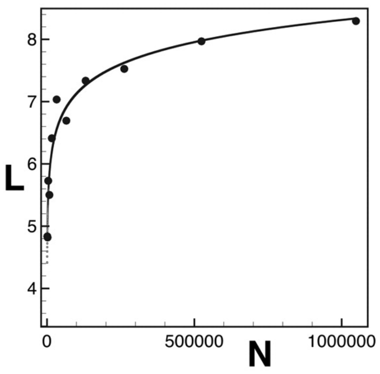
Muchos usos, clasificación, caracterización, identificación...

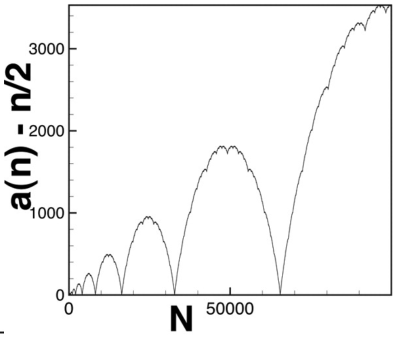


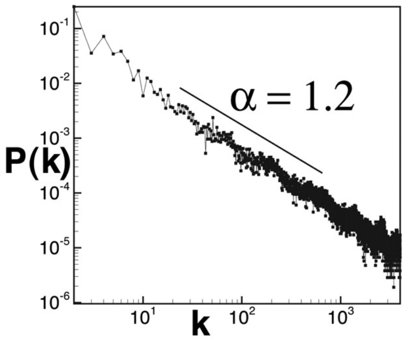


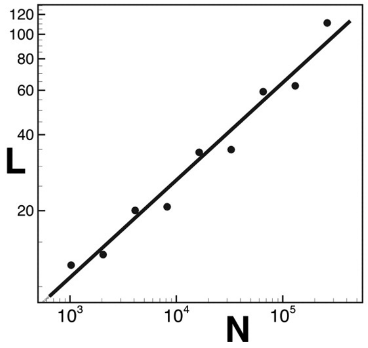


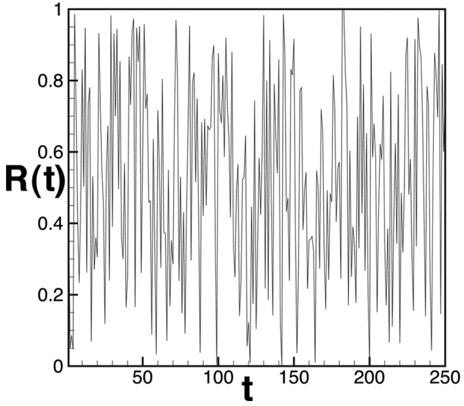


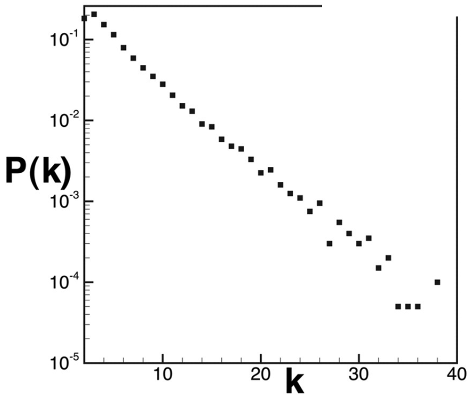












From time series to complex networks: The visibility graph

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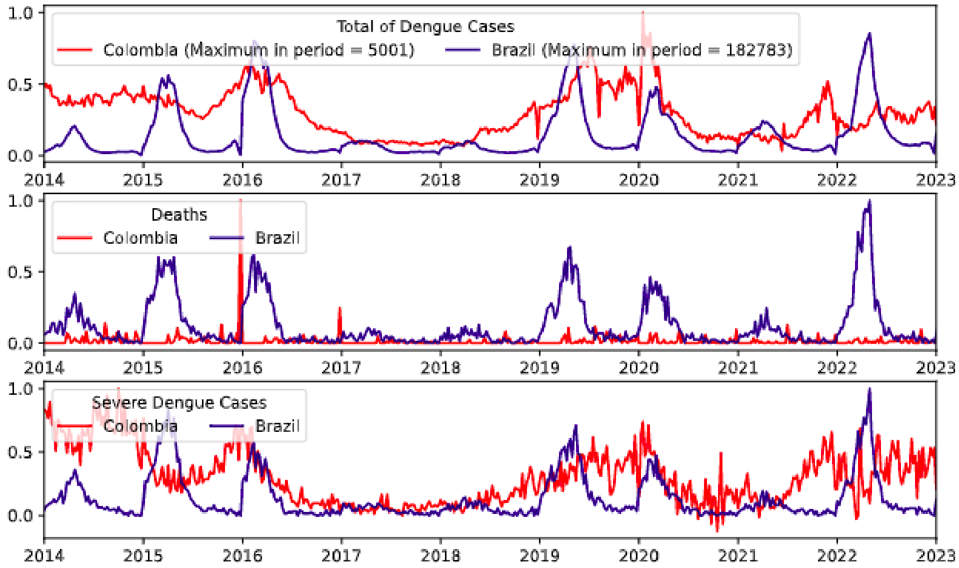
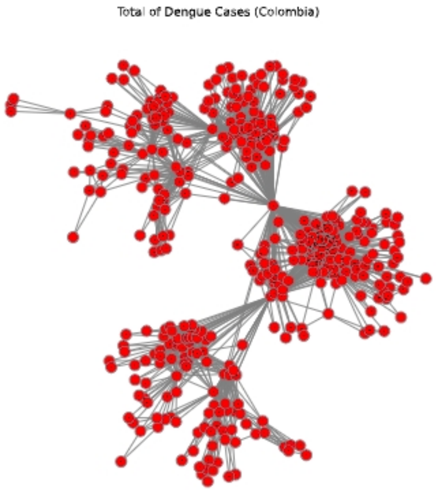
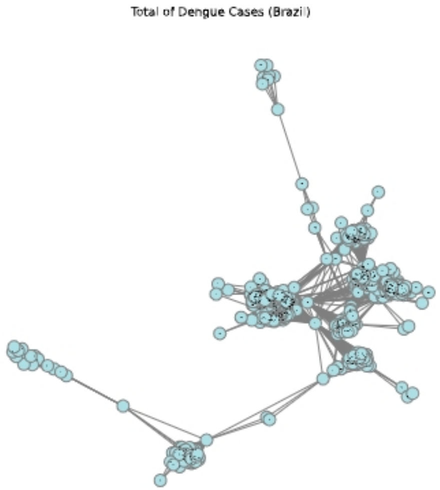
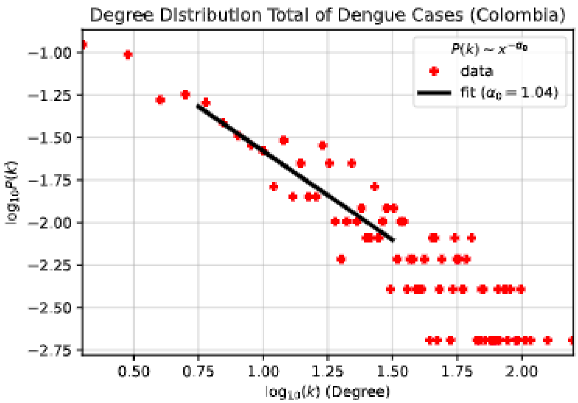
https://doi.org/10.1073/pnas.0709247105

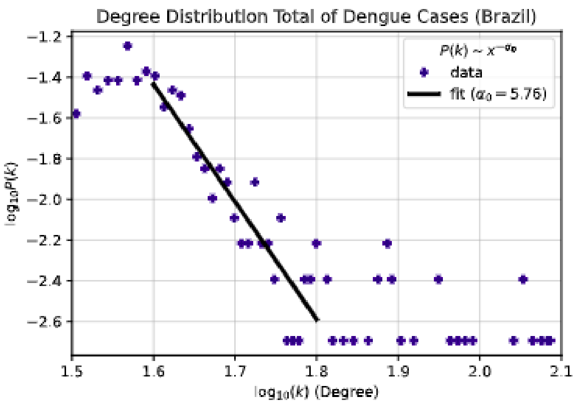
...Por ejemplo...


Total of Dengue Cases
Colombia (Maximum in period = 5001)
Brazil (Maximum in period = 182783)
Deaths
Colombia
Brazil
Severe Dengue Cases
Colombia
Brazil
1.0
0.5
0.0
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023


Total of Dengue Cases (Colombia)

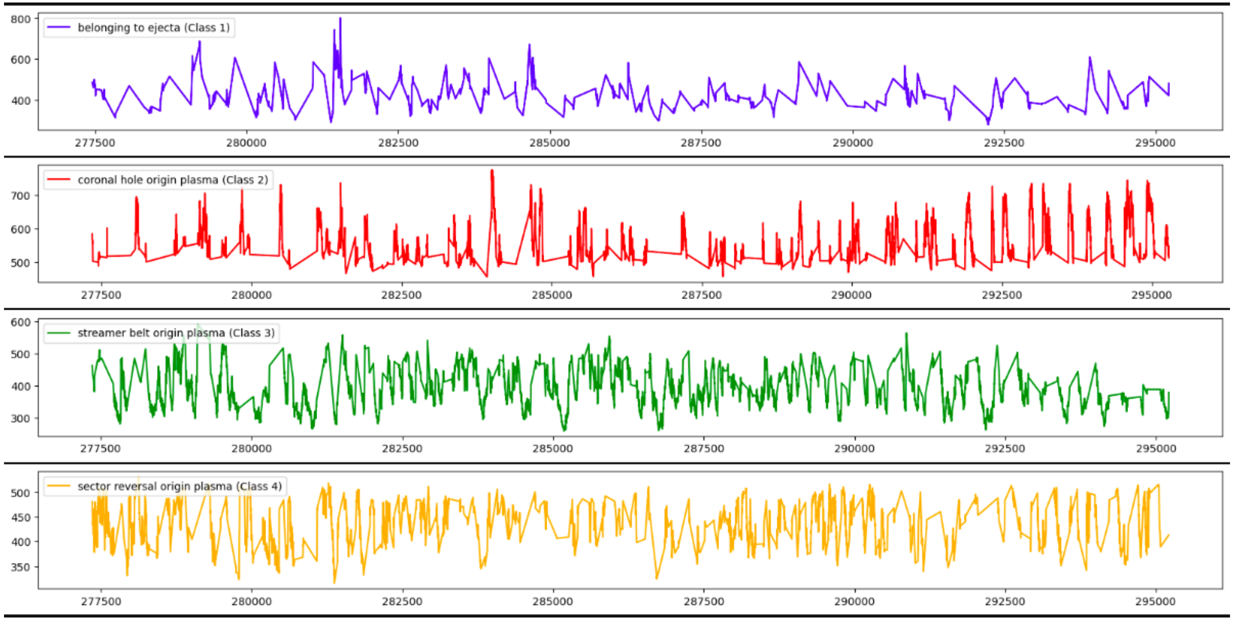

Total of Dengue Cases (Brazil)


Degree Distribution Total of Dengue Cases (Colombia)
$P(k) \sim x^{-\alpha_0}$
data
fit ($\alpha_0 = 1.04$)
$\log_{10}P(k)$
$\log_{10}(k)$ (Degree)
−1.00
−1.25
−1.50
−1.75
−2.00
−2.25
−2.50
−2.75
0.50
0.75
1.00
1.25
1.50
1.75
2.00

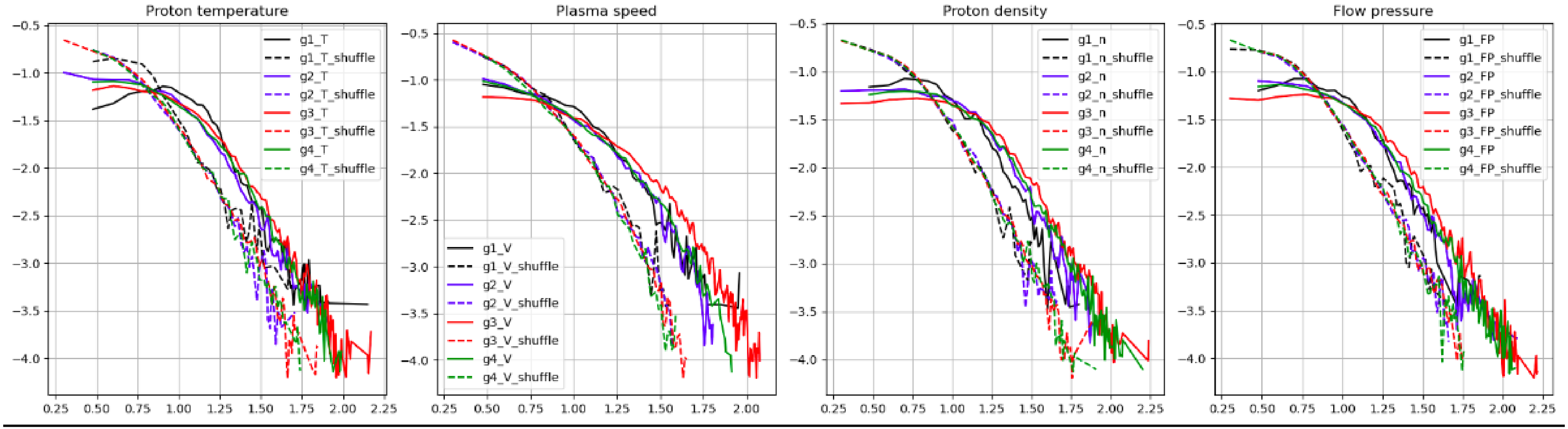

Degree Distribution Total of Dengue Cases (Brazil)
$P(k) \sim x^{-\alpha_0}$
data
fit ($\alpha_0 = 5.76$)
$\log_{10}P(k)$
$\log_{10}(k)$ (Degree)
−1.2
−1.4
−1.6
−1.8
−2.0
−2.2
−2.4
−2.6
1.5
1.6
1.7
1.8
1.9
2.0
2.1

...De vuelta a nuestro caso...

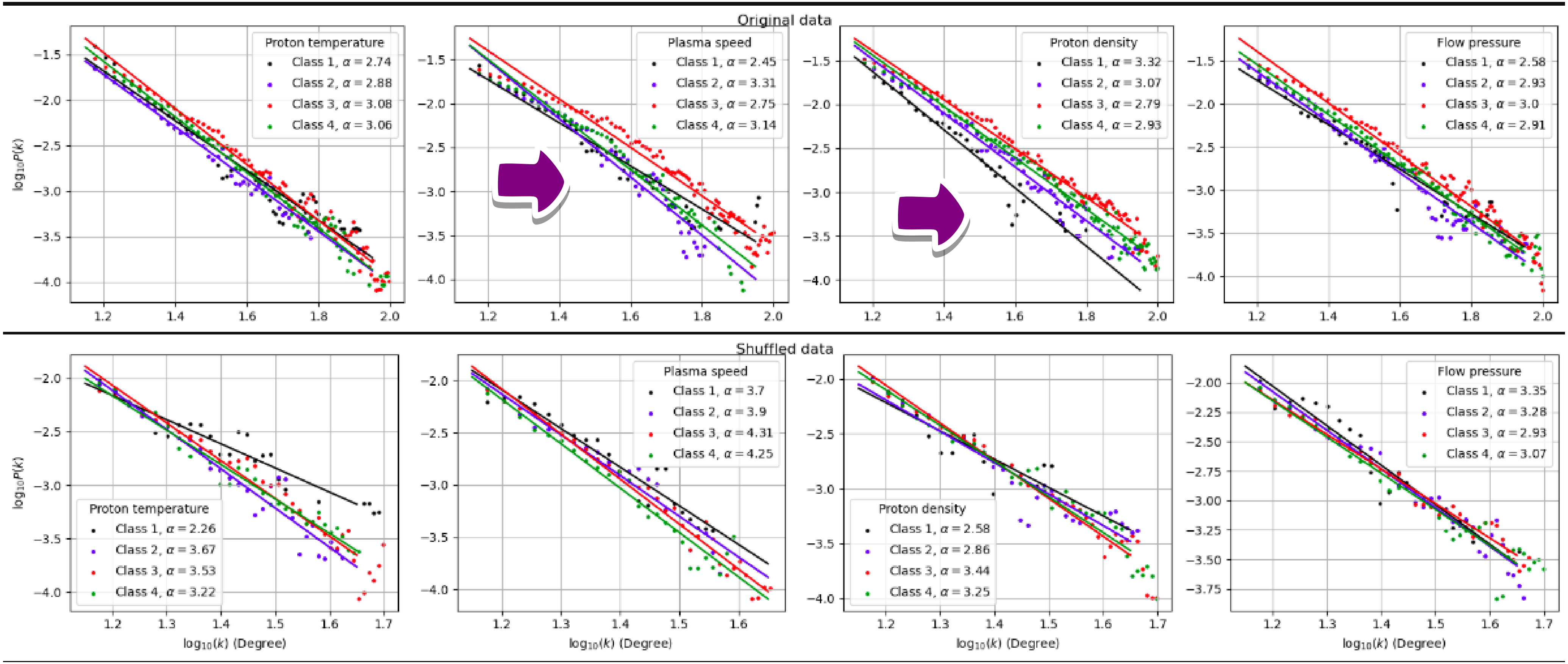
La gráfica muestra, la temperatura del viento Solar para diferentes fuentes de radiación



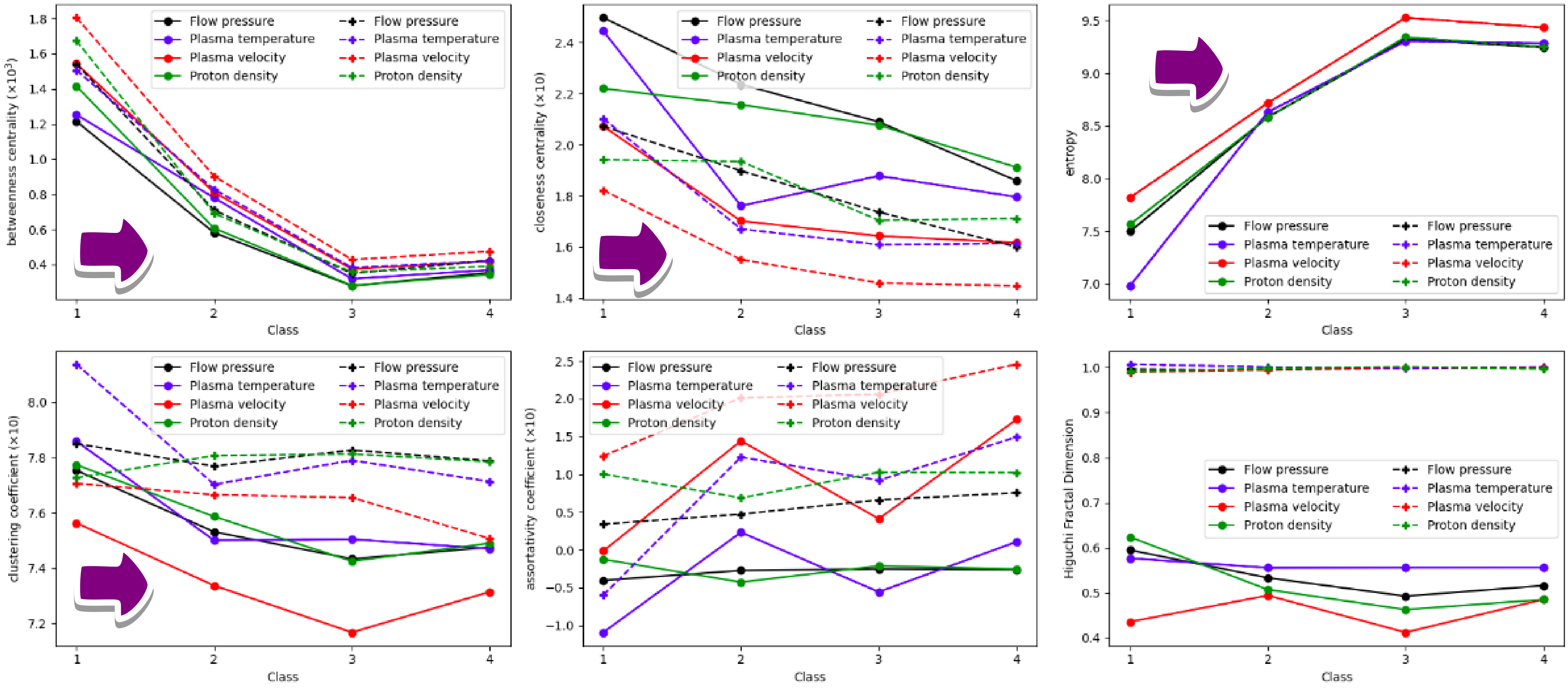
La gráfica muestra, el resultado de HVG sobre algunas las series de parámetros del viento solar



Cuando hacemos un poco de zoom en la región cuasi-lineal….



Y así cambian algunas medidas de entropia y caracterización del grafo de cada una de las series de tiempo...



A practicar un poco...

https://github.com/sierraporta/Ejercicio_HorizontalVisibilityGraph