Characterizing Colored Noise Time Series Patterns with Deep Learning Models

Ph.D. Candidate in Applied Computing

Luan Orion Baraúna
luan.ferreira@inpe.br
github.com/barauna-lo

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BRASIL
UNIÃO E RECONSTRUÇÃO

Luan Orion Baraúna

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INPE

Physicist - UFBA

Bachelor, Teacher degree and Master’s in physics (cosmology)

MBA in Data Science and Big Data – PUC Minas

Structure of the data, data clean, data analyze, data science pipe-line

PhD in Applied Computing - INPE

Emphasis in Artificial Intelligence in Time Series, Astronomical data analyses

Teacher

Elementary School, High School, College, Young Adult Special Education

Research

Cosmology, Deep Neural Network, Educational tools, time series data analyse

Collaborations

(Radio) BINGO Radio telescope - (Visible) LSST – (High Energy) ????

Free time

Sports, hiking, cycling, running, reading, video games


You Are Art
OVERCOME


Die findes des endes
@flep98
@sarahsarah16
FAU FRIEDRICH-ALEXANDER UNIVERSITÄT

Proposes

SamBa TimeS - **São** Paulo **meets Ba**varia: A **Time S**eries Workshop

L. Baraúna, S. Bouma, F. Eppel and S. Wagner

Although the underlying physics may be very different, similar challenges arise in time series analysis in various areas of astrophysics. This proposal aims to facilitate the exchange of algorithmic tools as used and developed for radio, multi-wavelength and radio neutrino astronomy, in order to help tackle outstanding issues in each field.

This exchange would culminate in the **organization of two one-day workshops on time series analysis** at the University of Würzburg and at the National Instituto of Space Research São Paulo (INPE). Through this series of gatherings, we aim to facilitate an intensive and dynamic exchange of diverse data analysis tools. We plan to have one person from Brazil contribute his expertise to the Würzburg workshop and three people from ECAP/JMU Würzburg contributing to the Brazil workshop. The workshops will be organized by a joint team from ECAP, JMU Würzburg and INPE and will be targeted to master and PhD students. We will organize a one-day program consisting of talks on basic principles of time series analysis (i.e. Basics Time Series Features Extractions, Data denoising, Forecast Time series, Machine Learning classical tools, Deep learning classifications, Bayesian block analysis) and provide hands-on sessions to share our knowledge and software tools within the participating institutions.

In advance to the workshop, the members of the proposing team will start collaborating on individual projects revolving around time series analysis. Throughout the week of the workshop, the proposed team will intensively discuss these projects and the applied methods together. Our collaboration intends to use this opportunity to solve several problems in high-energy astrophysics in the multi-messenger era:

Identifying Radio Neutrinos interaction with Deep Learning

Luan Orion Baraúna, Sjoerd Bouma

May 2023

Current (e.g. ARA, ARIANNA, RNO-G) and future (IceCube-Gen2) radio-based in-ice neutrino observatories aim to detect astrophysical neutrinos at ultra-high energies (UHE) of over 10 PeV. However, accurately identifying neutrino-induced events in time series data can be challenging, especially as a significant fraction of recorded events is expected to have a low signal-to-noise ratio (SNR). In recent years, deep learning (DL) has shown great potential in handling such complex data and achieving high classification accuracy [4]. In this proposal, we aim to explore the use of DL techniques, such as recurrent neural networks and convolutional neural networks, for the classification of radio and neutrino interactions in time series data. Our goal is to develop a robust and accurate classification model that optimized in High Performance Computing that can help astrophysicists better understand the behavior of high-energy particles in the universe. This research has the potential to contribute significantly to the field of astrophysics and advance our understanding of the universe's most energetic phenomena.

In order to reconstruct the direction of these neutrinos, both 'standard' [5] and DL based [3] reconstruction algorithms have been or are currently being developed. While better performance may be expected from the latter, the former may help more in terms of identifying current bottlenecks and thus potential areas of improvement. In particular, in [5], it was found that one of the main limiting factors was the reconstruction of the interaction vertex, with the challenge lying in correctly identifying the position of the neutrino pulse at low SNR. This is currently done using template correlation (see Fig.1). One of the aims of this project would be to investigate to what extent this aspect of the reconstruction could be improved by using a neural-network approach.

Another avenue that might be investigated is the classification of neutrino versus non-neutrino events, where the latter could be either thermal-noise-induced events or pulses induced by other phenomena, e.g. triboelectric [1] or anthropogenic sources. This classification has previously been done using e.g. a Fisher discriminant in [2], but here also improvements may be achieved by using a neural network.

I Workshop SaMBa Times (São Paulo Meets Bavaria - A Time Series Workshop)

Publicado em 25/03/2024 15h11 | Atualizado em 03/04/2024 14h52

O Workshop bilateral entre os Estados de São Paulo (Brasil) e Bavaria (Alemanha) é fruto de uma proposta de trabalho que aconteceu na 1ª parte do workshop “High-energy astrophysics in the multi-messenger era”, realizado em Erlangen Maio de 2023.

SamBa TimeS

sexta-feira 5 de abr de 2024 09:00 → 23:00 America/Sao_Paulo

Florian Eppel (JMU Würzburg), Luan Orion Baraúna (National Institute for Space Research), Sarah Wagner (Uni Wü), Sjoerd Bouma (ECAP)

Descrição São Paulo meets Bavaria - A Time Series Workshop

Although the underlying physics may be very different, similar challenges arise in time series analysis in various areas of astrophysics. The SamBa TimeS workshop aims to facilitate an intensive and dynamic exchange of algorithmic tools developed for radio, multi-wavelength and radio neutrino astronomy.

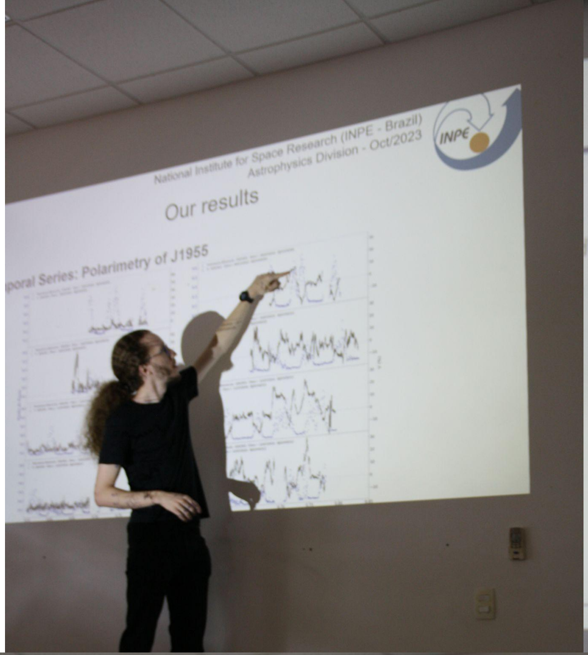
The workshop is hosted at the National Instituto of Space Research São Paulo (INPE). It is organized by a joint team from ECAP (Germany), JMU Würzburg (Germany) and INPE (Brazil) and is targeted to master and PhD students. Bachelor students and Post-Docs are also welcome to join. The one-day program consists of talks on basic principles of time series analysis (i.e. basic time series features, extractions, data denoising, forecasting, machine learning classical tools, deep learning classifications, bayesian block analysis), followed by hands-on sessions to share our knowledge and software tools within the participating institutions.

Some of the problems that will be discussed include:

- **Fast Radio Burst (FRB) detection methods and RFI classification**: The detection and processing of transient radio data is a major challenge in radio astronomy and both sides of the collaboration will profit from joint analysis tools that can be deployed for the BINGO and Effelsberg telescopes to perform searches for new Fast Radio Bursts. We will improve existing tools and expand them using Machine Learning (ML) methods which will contribute to the on-going search for the progenitor of FRBs.
- **Multi-wavelength light curve analysis**: Our team has immediate access to radio, X-ray and γ-ray data of variable AGN sources. We are aiming to study variability properties (modulation index, periodicity) of these sources and perform multi-wavelength cross-correlation studies to constrain emission models in AGN.
- **Pulse identification of radio neutrino signals:** The identification of neutrino signals for in-ice radio neutrino observatories (RNO-G, IceCube-Gen2) in noisy data is a major challenge for both reconstruction and background rejection. We will attempt to use deep-learning methods to improve on existing approaches to this problem.

Registro Participants


05/04/2024, das 9h às 17h
Welcome to SaMBa TimeS!
F. Eppel, S. Wagner
CROSSROADS
GUITAR FESTIVAL
AUTHENTICITY


National Institute for Space Research (INPE - Brazil)
Astrophysics Division - Oct/2023
INPE
Our results
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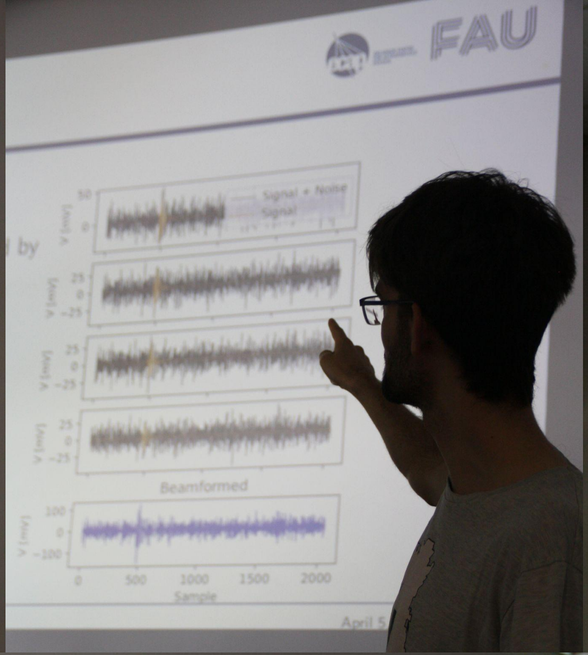
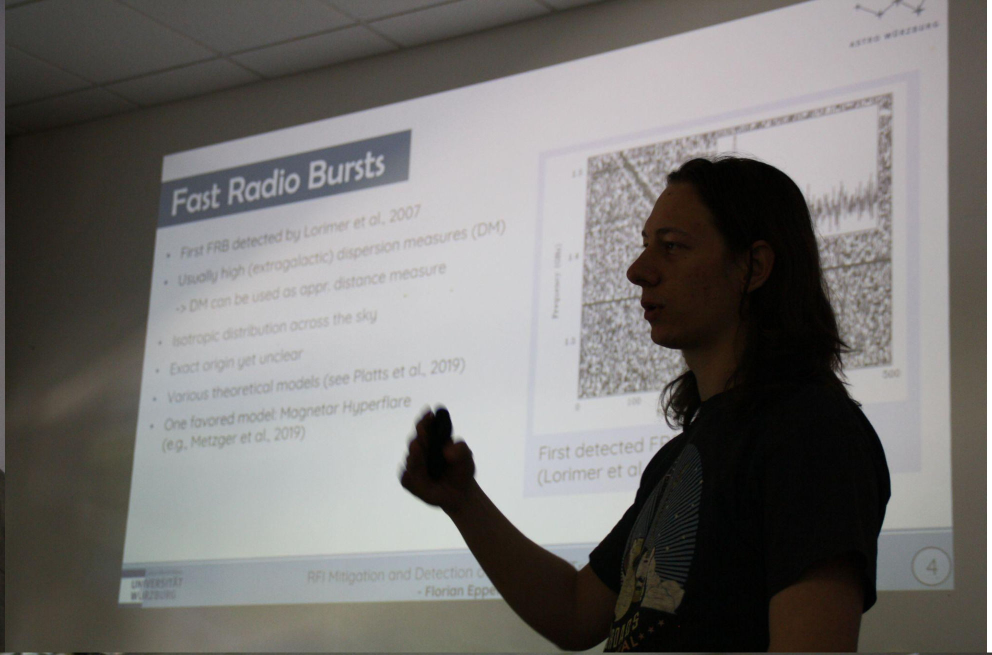

FAU
Signal + Noise
Signal
Beamformed
Sample
April 5


ASTRO WÜRZBURG
Fast Radio Bursts
First FRB detected by Lorimer et al., 2007
Usually high (extragalactic) dispersion measures (DM)
-> DM can be used as appr. distance measure
Isotropic distribution across the sky
Exact origin yet unclear
Various theoretical models (see Platts et al., 2019)
One favored model: Magnetar Hyperflare
(e.g., Metzger et al., 2019)
First detected FR
(Lorimer et al
RFI Mitigation and Detection o
- Florian Eppe
4


EGG
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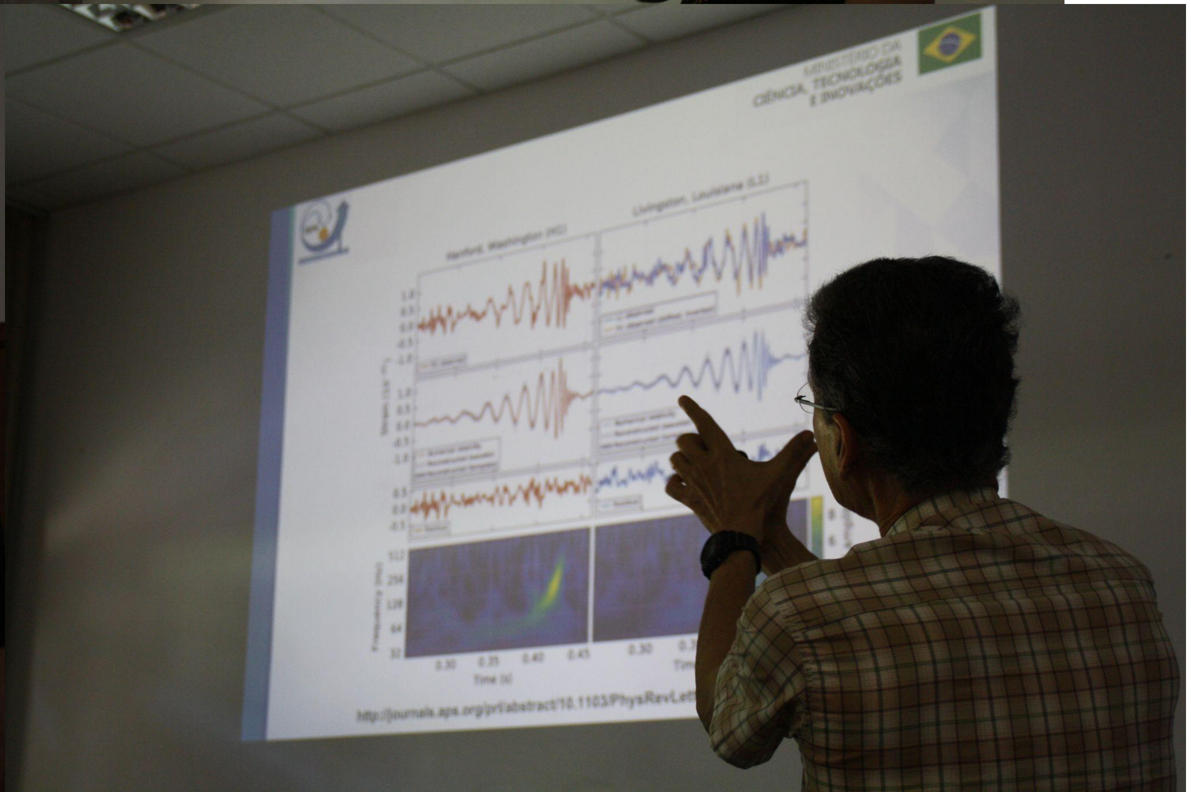
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Livingston, Louisiana (L1)
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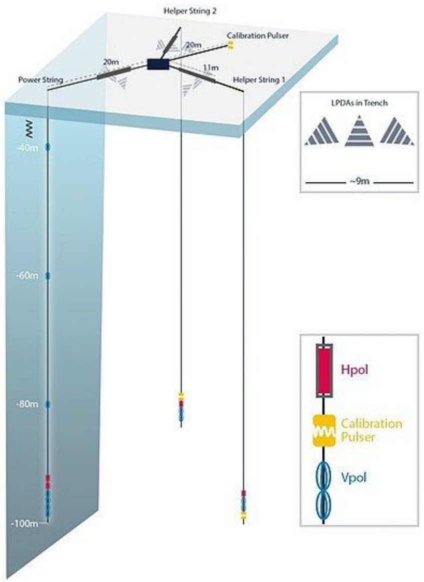
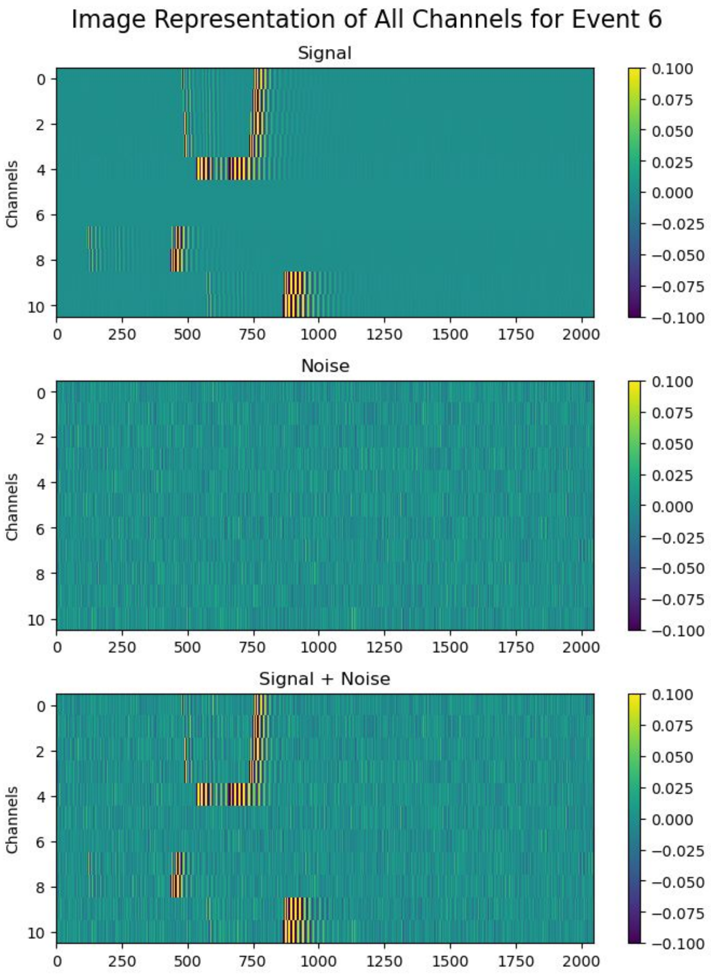
http://journals.aps.org/prl/abstract/10.1103/PhysRevLett

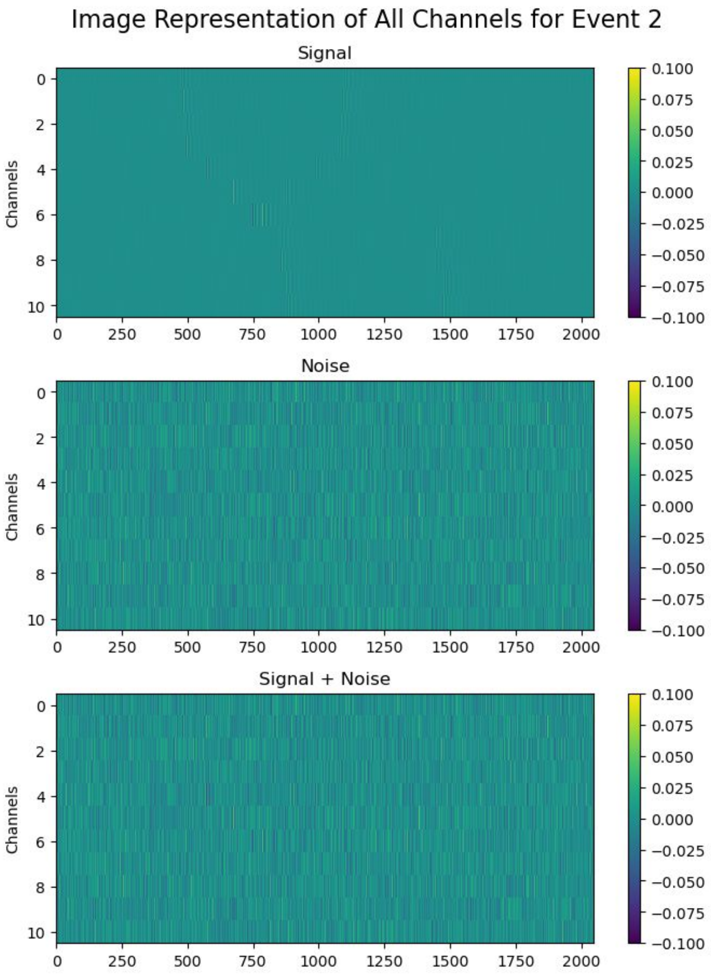

NÃO TOCAR

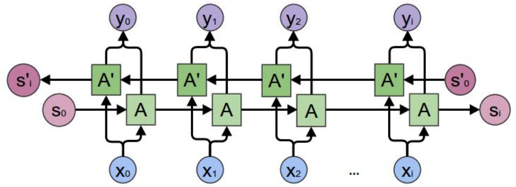
Identify Neutrinos With Deep Learning

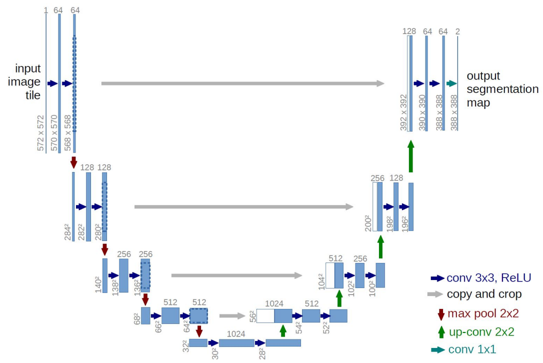
RNO-G
Radio Neutrino Observatory - Greenland

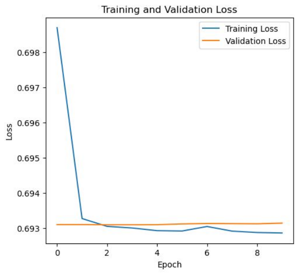




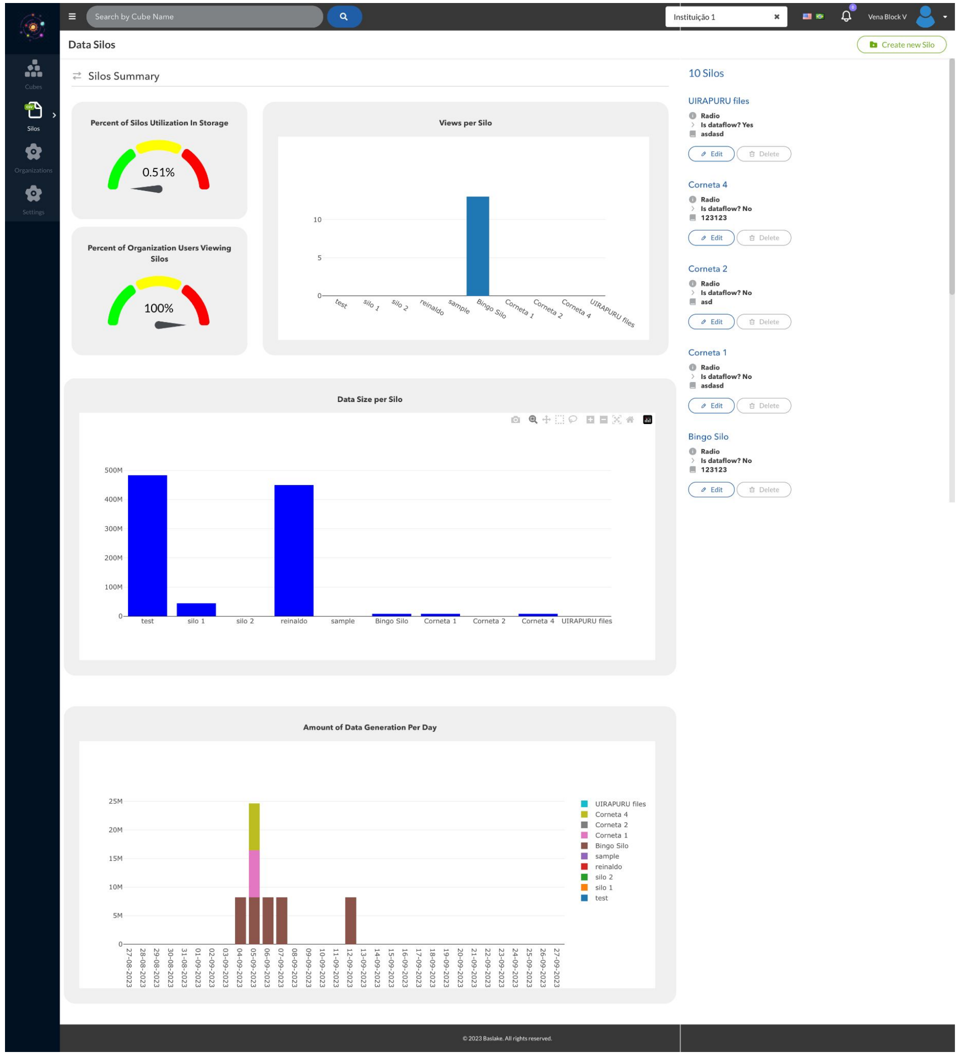


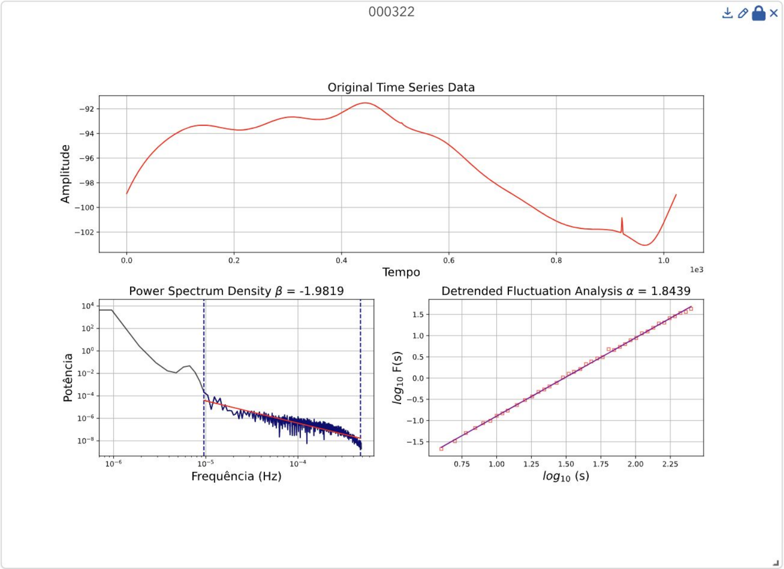


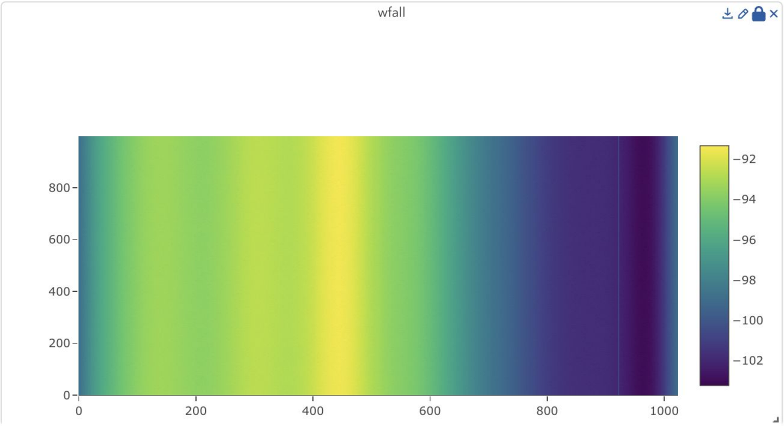


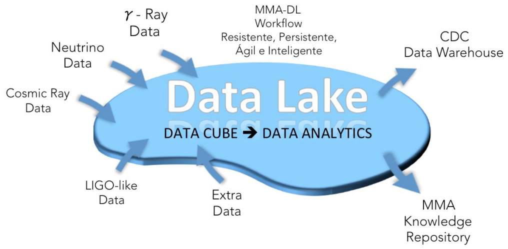


ADALA - Data Base For Radio Astronomy

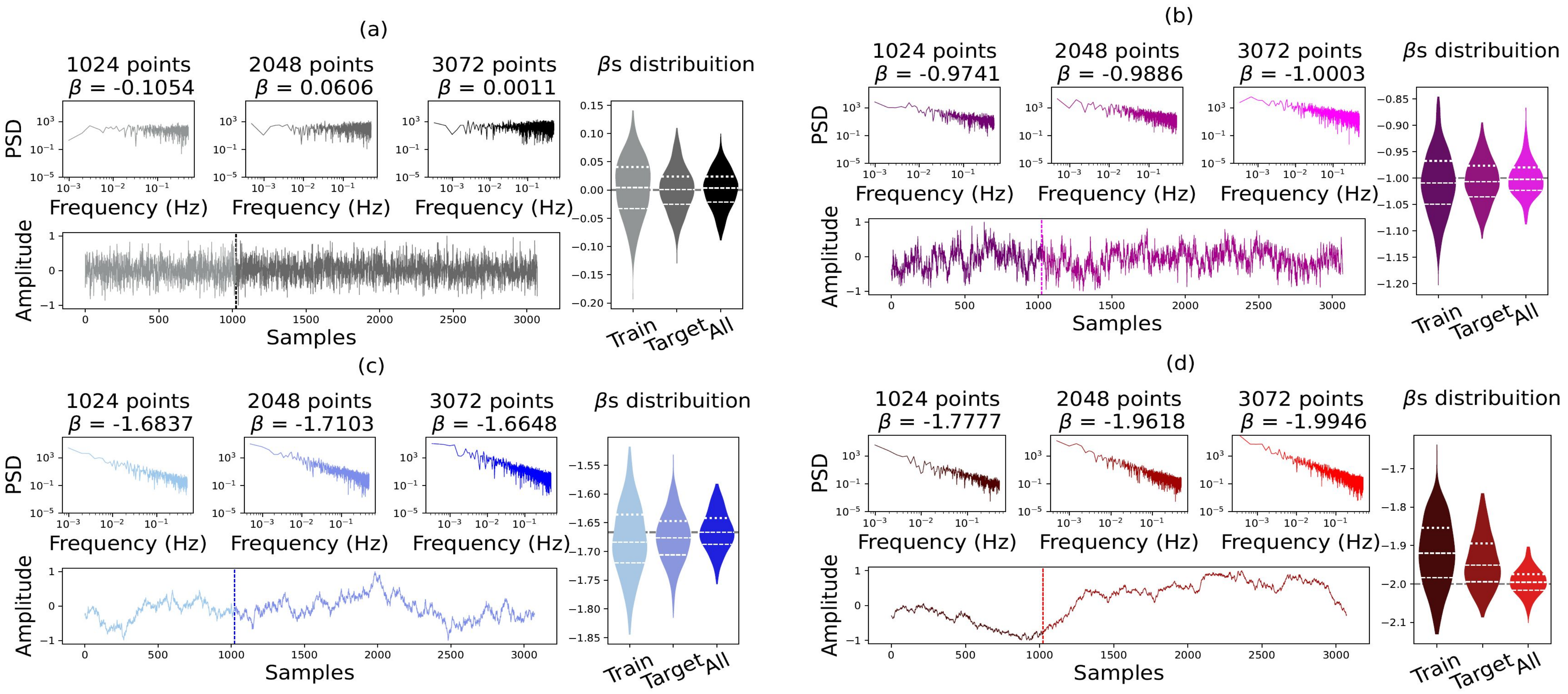








Characterizing Colored Noise Time Series Patterns with Deep Learning Models



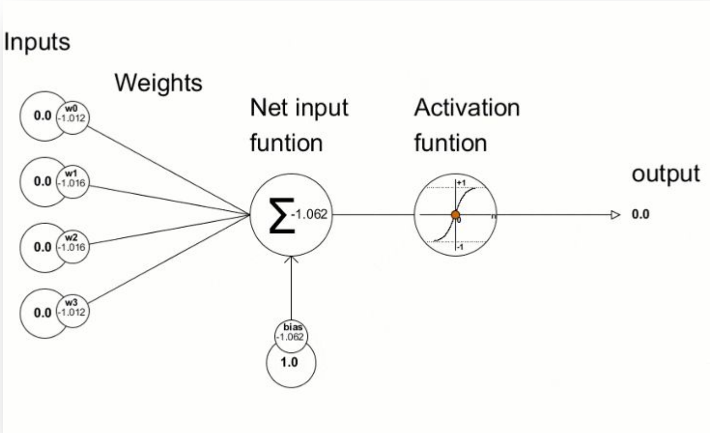
Characterizing Colored Noise Time Series Patterns with Deep Learning Models

$$P(\omega) = \left| \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} g(t) e^{-i\omega t}\, dt \right|^2$$

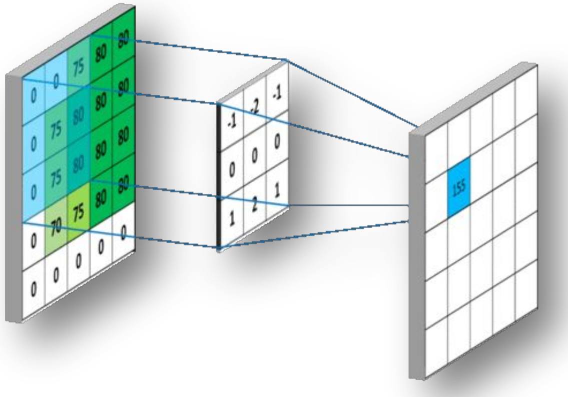
$$P(f) = \frac{1}{f^{\beta}},$$

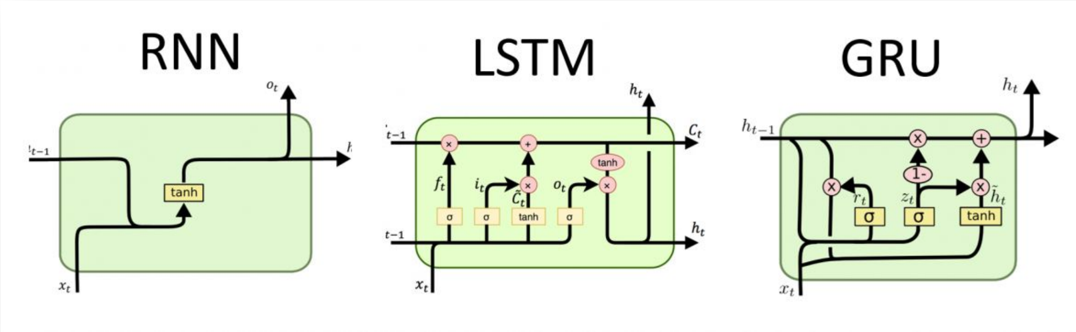
$$MSE_{PSD} = \frac{1}{N} \sum_{i=1}^{N} \left(\beta_i - \hat{\beta}_i \right)^2 .$$

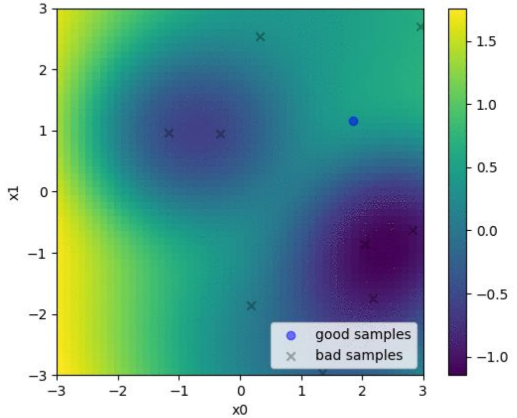
Multilayer Perceptron



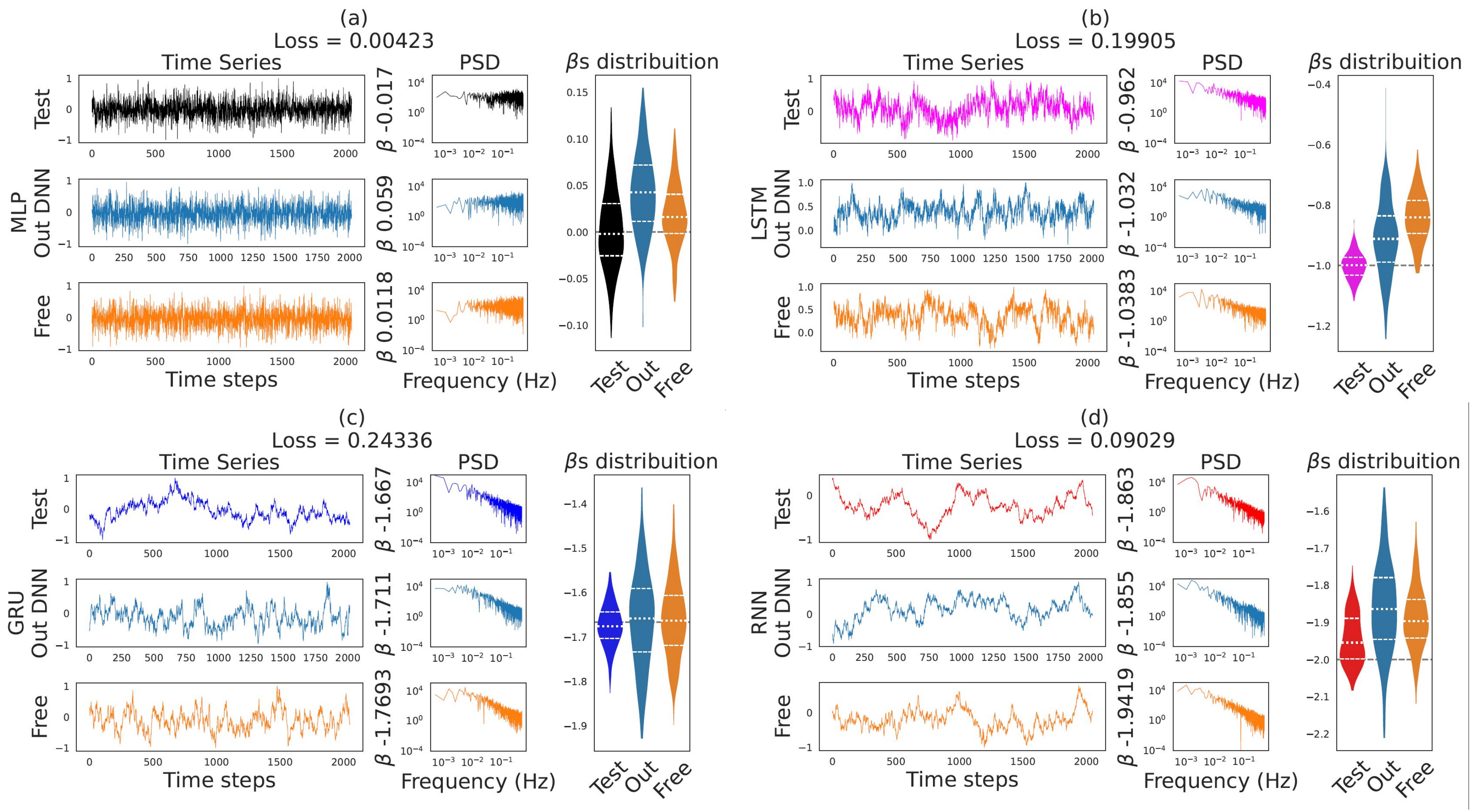
Convolutional Neural Network

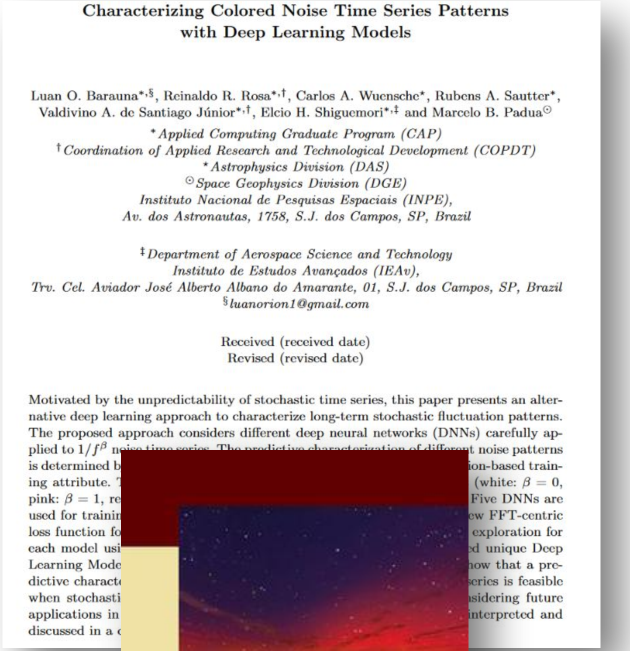






Characterizing Colored Noise Time Series Patterns with Deep Learning Models





Characterizing Colored Noise Time Series Patterns with Deep Learning Models

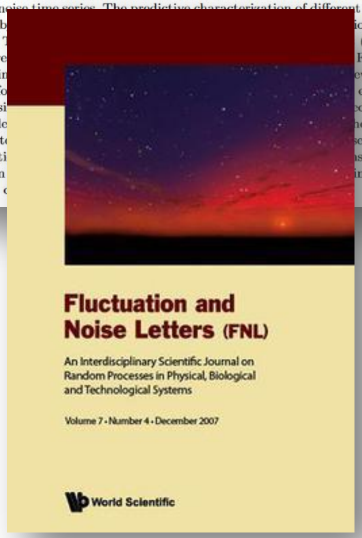
Luan O. Barauna*,§, Reinaldo R. Rosa*,†, Carlos A. Wuensche*, Rubens A. Sautter*, Valdivino A. de Santiago Júnior*,†, Elcio H. Shiguemori*,‡ and Marcelo B. Padua⊙

*Applied Computing Graduate Program (CAP)
†Coordination of Applied Research and Technological Development (COPDT)
*Astrophysics Division (DAS)
⊙Space Geophysics Division (DGE)
Instituto Nacional de Pesquisas Espaciais (INPE),
Av. dos Astronautas, 1758, S.J. dos Campos, SP, Brazil

‡Department of Aerospace Science and Technology
Instituto de Estudos Avançados (IEAv),
Trv. Cel. Aviador José Alberto Albano do Amarante, 01, S.J. dos Campos, SP, Brazil
§luanorion1@gmail.com

Received (received date)
Revised (revised date)

Motivated by the unpredictability of stochastic time series, this paper presents an alternative deep learning approach to characterize long-term stochastic fluctuation patterns. The proposed approach considers different deep neural networks (DNNs) carefully applied to $1/f^{\beta}$ ...



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entropy

MDPI

Article

Characterizing Complex Spatiotemporal Patterns from Entropy Measures

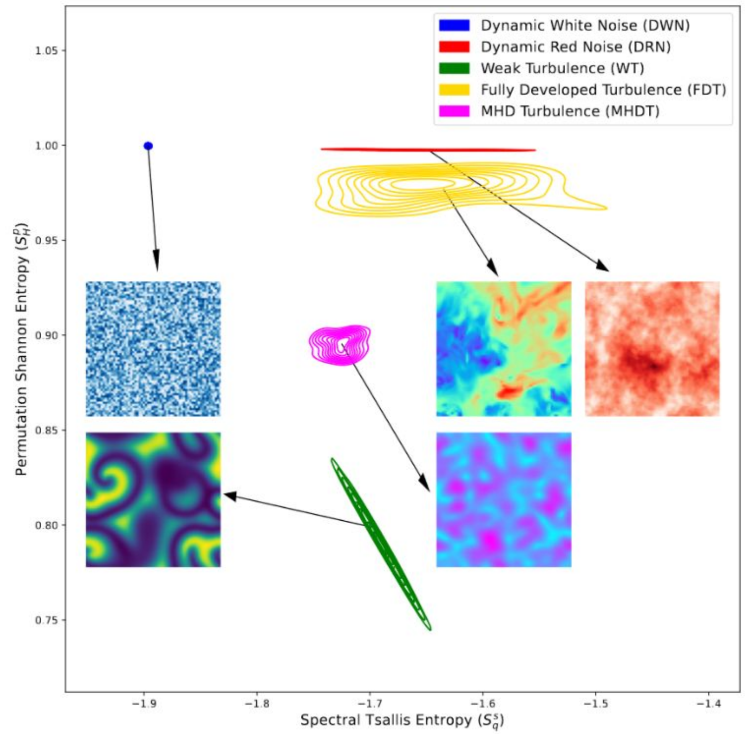
Luan Orion Barauna [1,*], Rubens Andreas Sautter [1], Reinaldo Roberto Rosa [1,2], Erico Luiz Rempel [3] and Alejandro C. Frery [4]

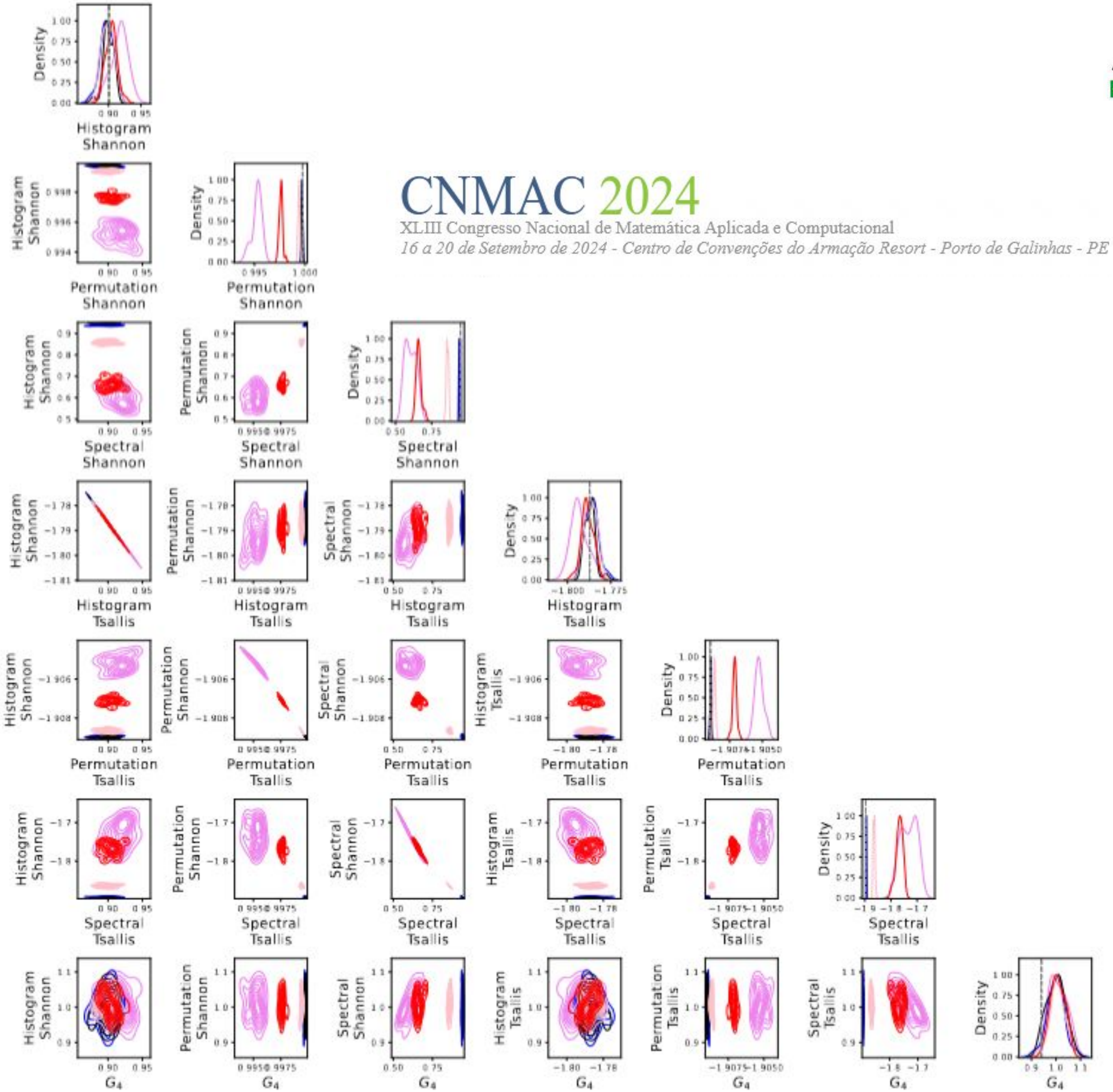
[1] Applied Computing Graduate Program (CAP), National Institute for Space Research, Av. dos Astronautas, 1.758, Jardim da Granja, 12227-01. São José dos Campos, São Paulo, Brazil: rubens.sautter@gmail.com
[2] Laboratory for Computing and Applied Math, National Institute for Space Research, Av. dos Astronautas, 1.758, Jardim da Granja, 12227-01. São José dos Campos, São Paulo, Brazil: reinaldo.rosa@inpe.br
[3] Mathematics Department, Aeronautics Institute of Technology, Praça Marechal Eduardo Gomes, 50. Vila das Acácias, 12228-900. São José dos Campos, São Paulo, Brazil: erico.rempel@ita.br
[4] School of Mathematics and Statistics, Victoria University of Wellington, PO Box 600 Wellington 6140, New Zealand: alejandro.frery@vuw.ac.nz
[*] Correspondence: luanorion1@gmail.com

Abstract: In addition to their importance in statistical thermodynamics, probabilistic entropy measurements are crucial for understanding and analyzing complex systems, with diverse applications in time series and one-dimensional profiles. However, extending these methods to two- and three-dimensional data still requires further development. In this study, we present a new method for classifying spatiotemporal processes based on entropy measurements. To test and validate the method, we selected five classes of similar processes related to the evolution of random patterns: (i) white noise; (ii) red noise; (iii) weak turbulence from reaction to diffusion; (iv) hydrodynamic fully developed turbulence; and (v) plasma turbulence from MHD. Considering seven possible ways to measure entropy from a matrix, we present the method as a parameter space composed of the two best separating measures of the five selected classes. The results highlight better combined performance of Shannon permutation entropy (S_H^p) and a new approach based on Tsallis Spectral Permutation Entropy (S_q^s). Notably, our observations reveal the segregation of reaction terms in this $S_H^p \times S_q^s$ space, a result that identifies specific sectors for each class of dynamic process, and it can be used to train machine learning models for the automatic classification of complex spatiotemporal patterns.

Citation: Barauna, L.O.; Sautter, R.A.; Rosa, R.R.; Rempel, E.L.; Frery, A.C.

Measure	Probability	Entropic Form	Reference
S_H^h	histogram	Shannon, Equation (3)	Lesne [21]
S_H^p	permutation	Shannon, Equation (3)	Pessa, Ribeiro [16]
S_H^s	spectral	Shannon, Equation (3)	Abdelsamie et al. [9], Abdullah et al. [3]
S_q^h	histogram	Tsallis q-law, Equation (4)	Li and Shang [22]
S_q^p	permutation	Tsallis q-law, Equation (4)	Li and Shang [22]
S_q^s	spectral	Tsallis q-law, Equation (4)	This paper
G_4	gradient	Complex Shannon, Equation (5)	Ramos et al. [18]





CNMAC 2024

XLIII Congresso Nacional de Matemática Aplicada e Computacional

16 a 20 de Setembro de 2024 - Centro de Convenções do Armação Resort - Porto de Galinhas - PE

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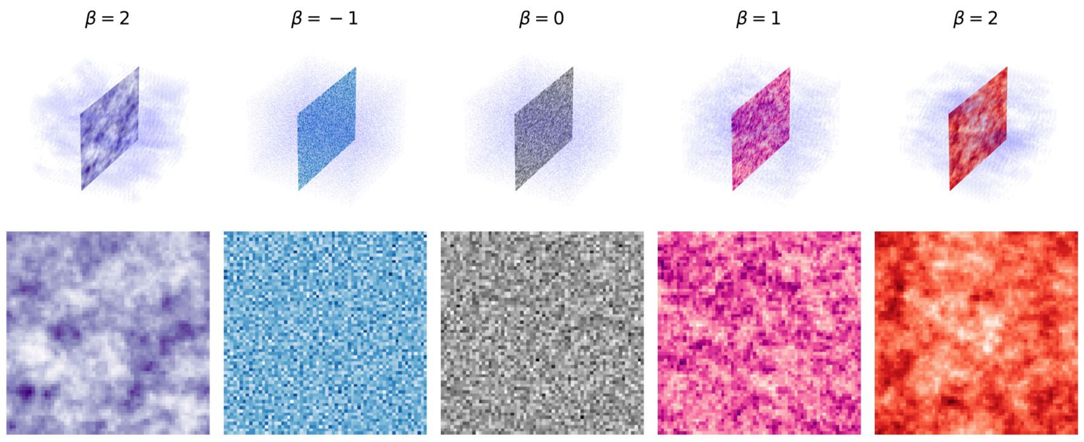
Proceeding Series of the Brazilian Society of Computational and Applied Mathematics

`eta`: A computational tool for data clustering in multidimensional entropy space in `python`

Baraúna L. O.[1], Sautter R.[2], Rosa R. R.[3]
Applied Computing Program (CAP), INPE-MCTI, São José dos Campos, SP

Abstracct. This study introduces a groundbreaking algorithm that leverages entropy measurements for the classification of complex spatiotemporal patterns `eta`. Focused on bridging the gap in multi-dimensional data analysis, the algorithm utilizes a novel combination of Shannon permutation entropy and Tsallis Spectral Permutation Entropy. This innovative approach not only distinguishes between various types of pattern evolutions and providing a structured parameter space for the effective segregation of dynamic processes. This advancement opens new avenues for the automatic classification of complex patterns, with significant implications for enhancing machine learning models.

Key-words. Entropy, python, Permutation Entropy, GPA)



High-energy astrophysics in the multi-messenger era

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Thank you

github.com/barauna-lo
linkedin.com/in/barauna-lo/
orcid.org/0000-0002-5214-2399
@orionba
luanorion1@gmail.com
luan.ferreira@inpe.br