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Plan de Recuperación, Transformación y Resiliencia
GENERALITAT VALENCIANA Conselleria de Educación, Universidades y Empleo
GVANEXT Fondos Next Generation en la Comunitat Valenciana

ASFAE ASTROFÍSICA Y FÍSICA DE ALTAS ENERGÍAS

GRAMOLA

Miguel G. Folgado

Instituto de Física Corpupscular / CSIC

Marzo 2024, Alicante

VNIVERSITAT DE VALÈNCIA · UNIVERSITAT POLITÈCNICA DE VALÈNCIA · UNIVERSITAS Miguel Hernández · Universitat d'Alacant Universidad de Alicante · CSIC Consejo Superior de Investigaciones Científicas

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Ondas **GR**avitacionales, **A**xiones y **M**ateria **O**scura, **L**attice e Inteligencia **A**rtificial (**GRAMOLA**)

13
Senior researchers

10
Postdoctoral researchers

17
PhD students

More than 40
publications per year

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Neutrinos

Lattice

Dark Matter

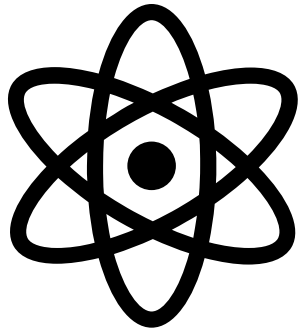
Cosmology

Artificial Intelligence

Flavour and Origin of Matter

Sabor y Origen de la Materia

What unites us?



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299.843 €
Granted

PostDoctoral Researcher

New HPC equipment

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HPC equipment before 2023

Hostname	N. Cores / Threads	Memory	Disk Size	GPUs	Operating System	Acquisition year
som1@ific.uv.es	12/24	192 GB DDR3	2 x HD SATA3 3TB 1 x HD SATA3 1TB	1 x NVIDIA TESLA M2090	Scientific Linux 6.1	2011
som2@ific.uv.es	32/64	512 GB DDR3	3 x HD SATA3 3TB	None	Scientific Linux 6.2	2012
som3@ific.uv.es	32/64	512 GB DDR3	6 x HD SATA3 4TB (RAID 5)	None	Scientific Linux 6.5	2013
som4@ific.uv.es	32/64	512 GB DDR3	2 x HD SATA3 6TB (RAID 1) 1 x HD SSD 480GB	None	Scientific Linux 7.0	2014
som5@ific.uv.es	36/72	372 GB DDR4	1 x HD SSD 4 TB 5 x HD SAS3 2 TB (RAID 5)	1 x NVIDIA TESLA V100 1 x NVIDIA TESLA T4	CentOS 8	2021
som6@ific.uv.es	56/112	512 GB DDR4	12 x HD SAS3 14 TB (RAID 5)	None	Rocky Linux 8.8	2021
somdisk@ific.uv.es	2/4	4 GB DDR3	2 x HD SATA3 4 TB (RAID 1) 6 x HD SATA3 6 TB (RAID 5) 4 x HD SATA3 8 TB (RAID 5)	None	Synology DSM	2014

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som4@ific.uv.es	32/64	512 GB DDR3	2 x HD SATA3 6TB (RAID 1) 1 x HD SSD 480GB	None	Scientific Linux 7.0	2014
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gr02	WN	56/56	256 GB DDR4	3 x HD SSD 1 TB (RAID 0)	2 x AMD EPIC(TM) 7453@2.75GHz	Supermicro AS-1024US-TRT
gr03	WN	56/56	256 GB DDR4	3 x HD SSD 1 TB (RAID 0)	2 x AMD EPIC(TM) 7453@2.75GHz	Supermicro AS-1024US-TRT
gr04	WN	56/56	256 GB DDR4	3 x HD SSD 1 TB (RAID 0)	2 x AMD EPIC(TM) 7453@2.75GHz	Supermicro AS-2024S-TR
gr05	WN	56/56	256 GB DDR4	3 x HD SSD 1 TB (RAID 0)	2 x AMD EPIC(TM) 7453@2.75GHz	Supermicro AS-2024S-TR
gr06	WN	56/56	256 GB DDR4	3 x HD SSD 1 TB (RAID 0)	2 x AMD EPIC(TM) 7453@2.75GHz	Supermicro AS-2024S-TR
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gr18	WN	56/56	256 GB DDR4	3 x HD SSD 1 TB (RAID 0)	2 x AMD EPIC(TM) 7453@2.75GHz	Supermicro AS-2024S-TR

New HPC equipment

1 x Disk Server (990 TB)

1 x GPU Server (AMD MI210)

18 x Worker nodes for parallel jobs (With IB)

2 x Worker nodes for serial jobs

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New HPC equipment

GRAMOLA

10 x Worker nodes for parallel jobs (With IB)

2 x Worker nodes for serial jobs

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List of HPC equipment purchased

Parallel Computing

10 x Working nodes:

- InfiniBand 200 Gb/s
- 2 x CPU AMD MILAN 7453 (28 cores, 2.75 GHz)
- Memory: 256 GB DDR4-3200

~ 95.000 €

Serial Computing

2 x Working nodes:

- 2 x CPU AMD GENOA 9454 (48 cores, 2.75 GHz)
- Memory: 384 GB DDR5-4800

~ 35.000 €

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On a robust analisis of the growth of structure

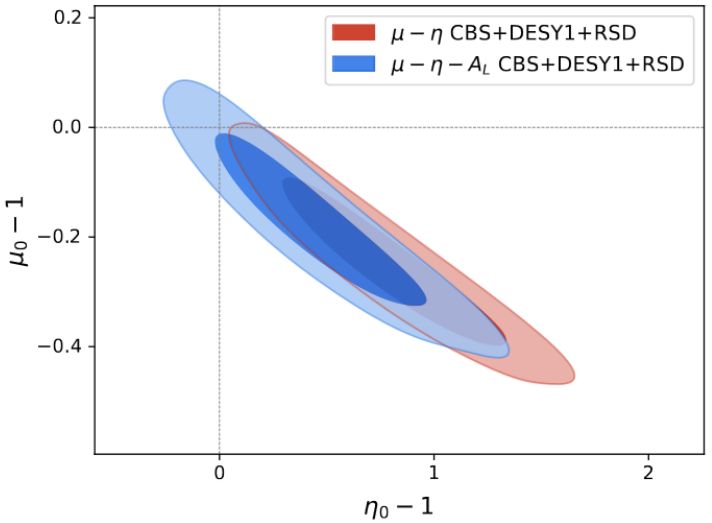
Deng Wang, Olga Mena

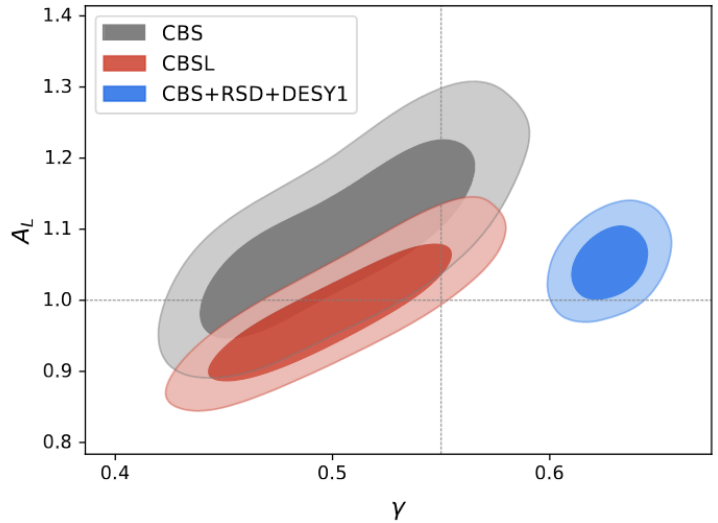
(arXiv:2311.14423)

Revisiting the tensions between growth structures and observational data

- Recent studies found a discrepancy between the growth index structure and ΛCDM cosmological model.
- Different growth parametrization could provide a richer análisis. The problem has been studied using two new functions to modify the Poisson equations, instead the parametrization in terms of one unique parameter used in previous works.
- CosmoMC (Cosmological MonteCarlo)

5000 core hours





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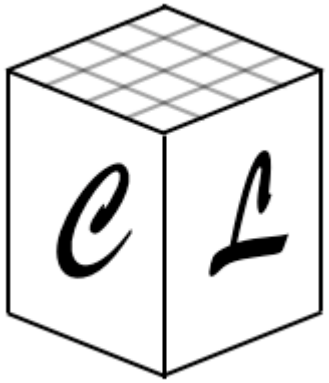
CosmoLattice

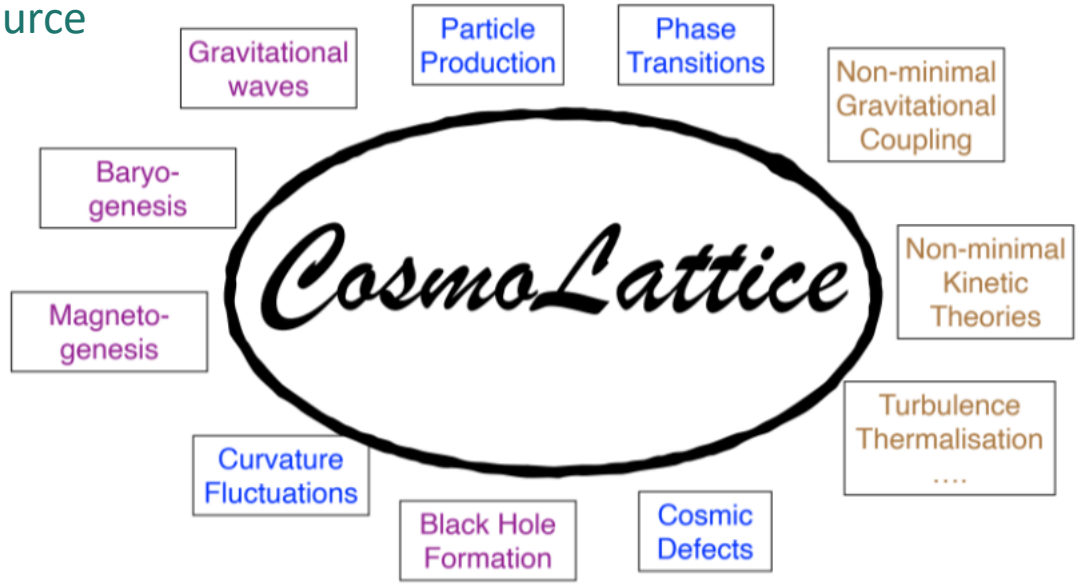
Daniel G. Figueroa, Adrien Florio, Francisco Torrenti & Wessel Valkenburg

(arXiv:2102.01031 & arXiv:2309.08430)



CosmoLattice

- A modern code for Lattice simulations of scalar and gauge field dynamics in an expanding universe.
- More tan 50 different works have used the Cosmolattice package since 2021.
- Open Source



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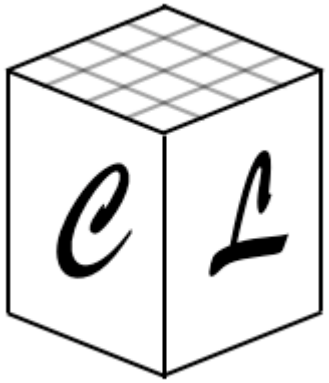

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Gravitational Wave Emission from a Cosmic String Loop, I: Global Case

Jorge Baeza-Ballesteros, Edmund J. Copeland, Daniel G. Figueroa, Joanes Lizarraga

arXiv:2308.08456

~ 2 – 3 M core hours

Gravitational wave production from preheating with trilinear interactions

Catarina Cosme, Daniel G. Figueroa, Nicolas Loayza

arXiv:2206.14721

~ 200 K core hours

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The determination of the strong coupling α_s

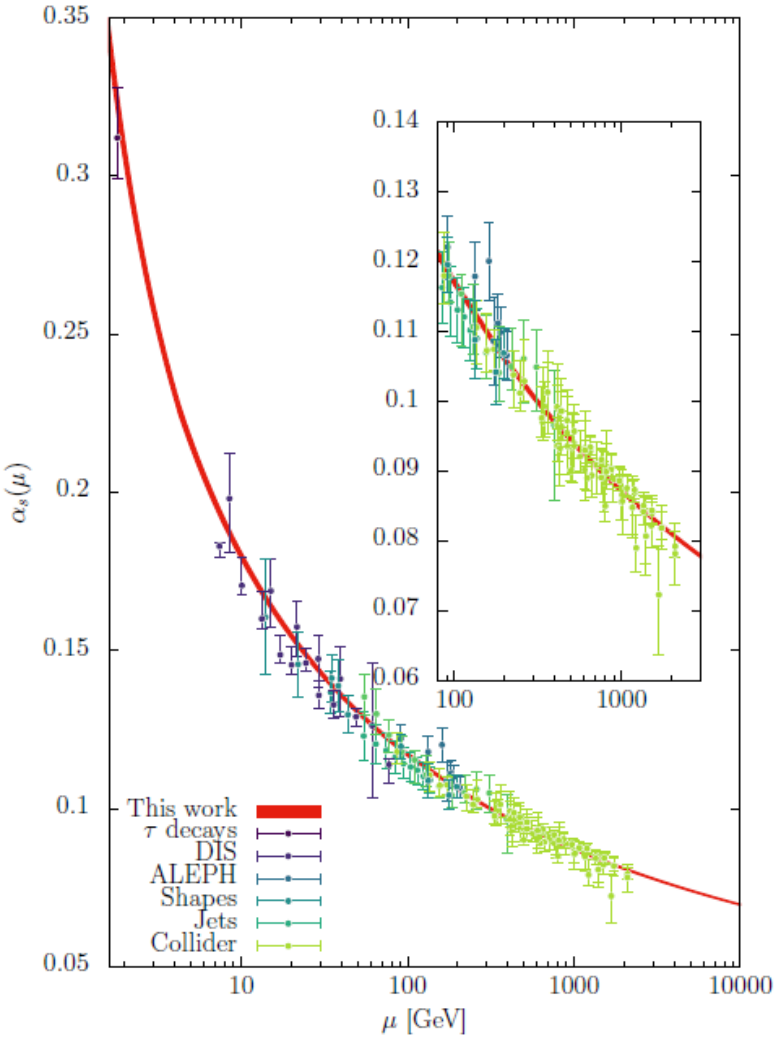
Alberto Ramos

α_s from Lattice QCD

- Computational approach to non-perturbative QCD
- Large computer needs $\mathcal{O}(10^8)$ core/hours (EuroHPC)
- Local facilities (in part financed by ASFAE), are fundamental
  - Development of new algorithms
  - Tuning of parameters
  - Smaller runs

Current determination dominates world average [PDG'21]

- Explains phenomena in a large range of energy scales.
- Theoretical uncertainties sub-dominant
- Improvement on the way!



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Reconstruction of Gravitational Wave Backgrounds

Androniki Dimitriou, Daniel G. Figueroa & Bryan Zaldívar

(arXiv:2309.08430)

Scope:

Study the *spectral shape* (cf. Fig.) of GW cosmological backgrounds, as potentially measured by LISA and other future detectors.

★ Statistical inference of the physical parameters with modern likelihood-free methods (Machine Learning-based).

★ Several practical advantages wrt typical MCMC methods (No likelihood assumption, faster at inference stage, …)

Software:

- **Julia** for the data simulation
- **Python & pyTorch** for the optimisation

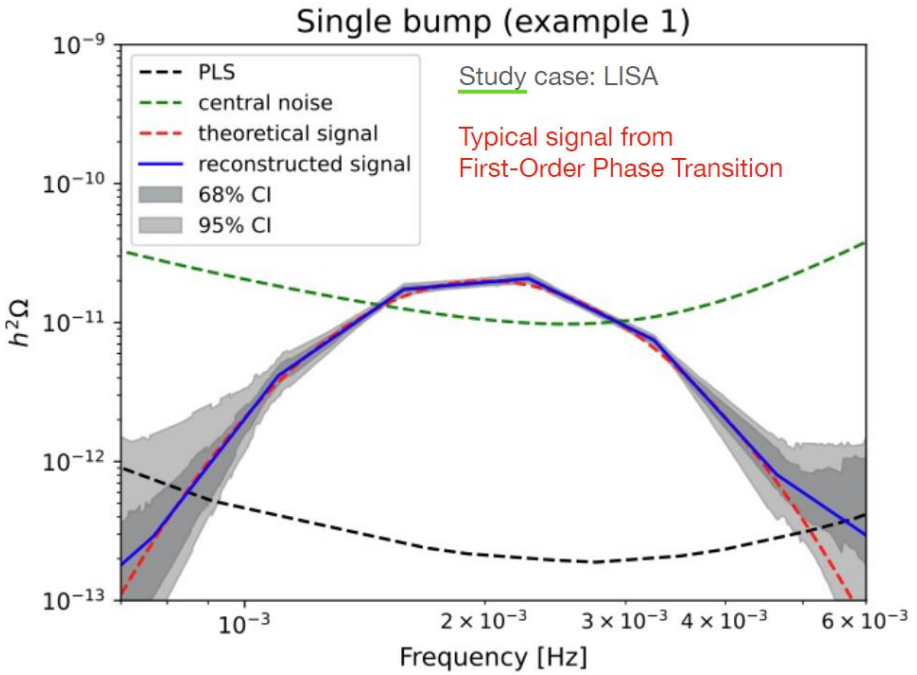
} Artemisa

ARTificial Environment for ML and Innovation in Scientific Advanced Computing

~ 200 core hours

Results:

- Efficient **blind reconstruction** even below the detector noise
- Successful inference also in presence of astrophysical foregrounds
- Public code in **GitHub**



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Baryon asymetry via neutrino oscillations

Pilar Hernández, Jacobo López-Pavón, Nuria Rius y Stefan Sandner

(arXiv:2207.01651 & arXiv:2305.14427)

Quantification of baryon asymetry generation via neutrino oscillations.

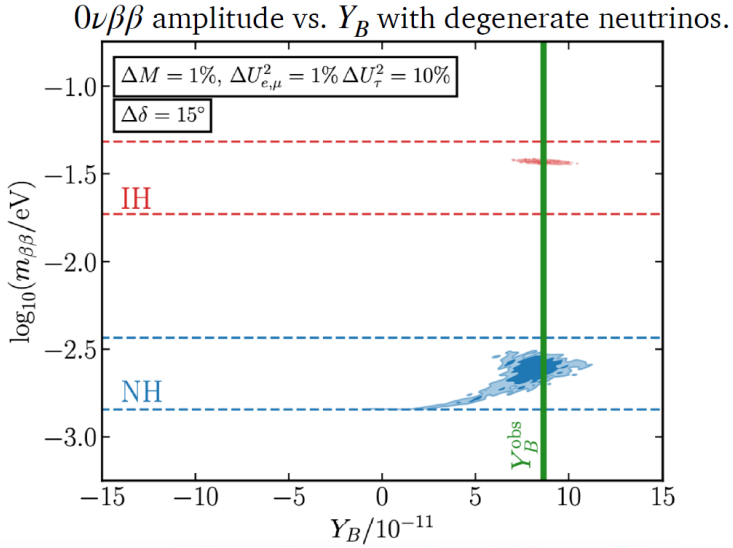
Solve: Stiff, non-linear 11-dimensional system of differential equations.

- Developed new C++ software paired with open source nested sampling algorithm to explore full parameter space.

GitHub

Integral part for efficient scan is parallelization to arbitrary number of CPU cores. 1 scan 2 days x 256 cores ~ 12.288 core hours

Reveal correlation between baryon asymmetry and other neutrino observables.



arXiv 2207.01651

arXiv 2305.14427

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Gravitational WIMP Dark Matter in Extra-Dimensions

Andrea Donini, Miguel G. Folgado, Nuria Rius

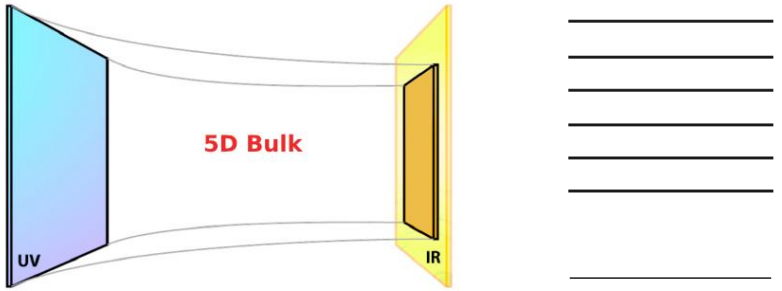
(arXiv:1907.04340, arXiv:1912.02689 & arXiv:2006.02239)

WIMP Dark Matter only with gravitational interactions?

It is possible, but only in extra-dimensional set ups!

Randall-Sundrum

$$ds^2 = e^{-2kr_c|y|}\eta_{\mu\nu}dx^\mu dx^\nu - r_c^2 dy^2$$

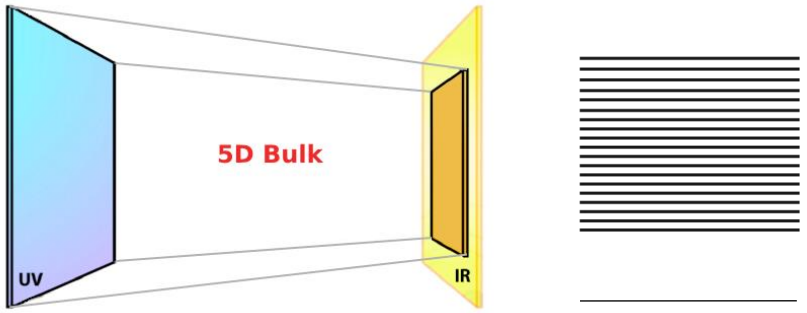


Mass spectra

$$\Lambda = \bar{M}_{pl}e^{-\pi r_c k} \ll \bar{M}_{pl}$$

Clockwork/Linear Dilaton

$$ds^2 = e^{\frac{4}{3}kr_c|y|}(\eta_{\mu\nu}dx^\mu dx^\nu - r_c^2 dy^2)$$



Mass spectra

$$\Lambda_n \propto \sqrt{M_5^3 \pi r_c} \sim k, M_5$$

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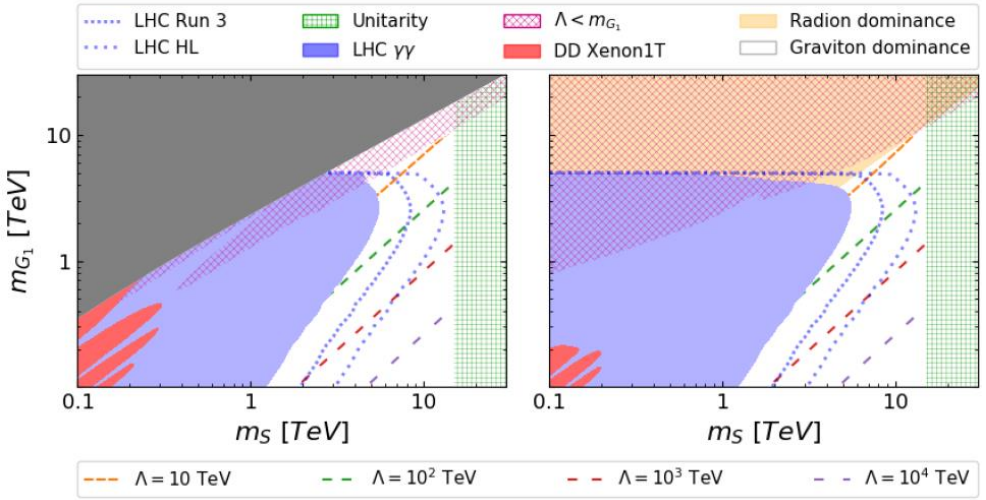
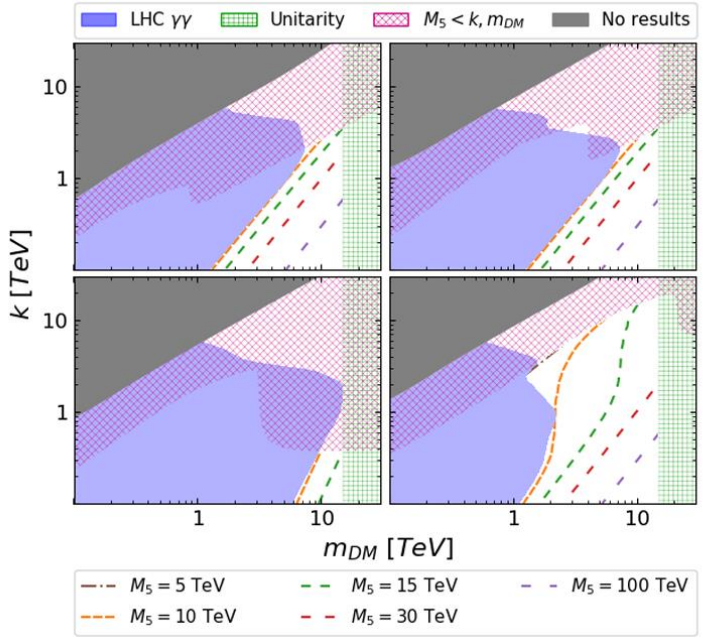


$$\Lambda, m_{G_1}, m_{DM}$$

Clockwork/Linear Dilaton



$$M_5, m_{G_1}, m_{DM}$$

The problem it is computationally expensive. How to solve it? Once again, the answer is parallelization.
We developed a C++ software to calculate the phenomenology.

~ 200 core hours

~ 400 core hours

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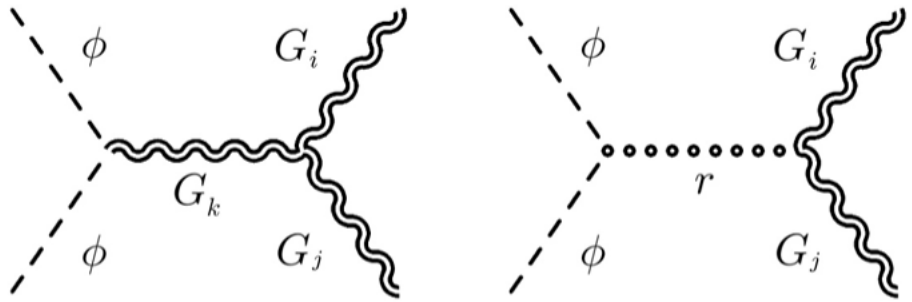
Gravitational WIMP Dark Matter in Extra-Dimensions

Andrea Donini, Miguel G. Folgado, Juan Herrero-García, Giacomo Landini, Alejandro Muñoz, Nuria Rius

Current Status:

- Adding extra-interactions that will modify the phenomenology



- Different theoretical set up

First proves:
Increases computational time

400 x 400 points

~ 10.000 core hours

The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

Interdisciplinary Research

Establishing a real-time traffic alarm in the city of Valencia with Deep Learning
Miguel Folgado, Verónica Sanz, Johannes Hirn, Edgar Lorenzo-Saez, Javier Urchueguia
arXiv:2309.02010

Predicting the traffic flux in the city of Valencia with Deep Learning
Miguel G. Folgado, Verónica Sanz, Johannes Hirn, Edgar G. Lorenzo, Javier F. Urchueguia
arXiv:2210.01630

Environment and climate change

~ 1.500 GPU hours

Exploring the political pulse of a country using data science tools
Miguel G. Folgado, Verónica Sanz
arXiv:2011.10264

Natural Lenguage Processing (NLP)

Exploring how a Generative AI interprets music
Gabriela Barenboim, Luigi Del Debbio, Johannes Hirn, Veronica Sanz
arXiv:2308.00015

Symmetry meets AI
Gabriela Barenboim, Johannes Hirn, Veronica Sanz
arXiv:2103.06115

Art & Music

Symmetry meets AI
D. Conde, F. L. Castillo, C. Escobar, C. García, J. E. García, V. Sanz, B. Zaldívar, J. J. Curto, S. Marsal, J. M. Torta
https://doi.org/10.22541/essoar.167839956.63152489/v1

Space Weather

A deep Generative Artificial Intelligence system to predict species coexistence patterns
Johannes Hirn, José Enrique García, Alicia Montesinos-Navarro, Ricardo Sánchez-Martín, Veronica Sanz, Miguel Verdú
https://doi.org/10.1111/2041-210X.13827

Ecology

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GVA NEXT · Fondos Next Generation en la Comunitat Valenciana

Summary

- The research of SOM group is a very active and diverse (as the acronym GRAMOLA suggests).
- Very diverse physics but united by a common denominator: Computationally expensive
- The funding provided by the GRAMOLA project has allowed us to renew and expand our HPC infrastructure.
- All of the research lines of the group will benefit from this

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Summary

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