

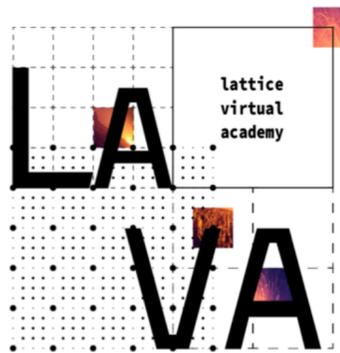
# Present and Future Perspectives in Hadron Physics

LNF 17-19 June 2024

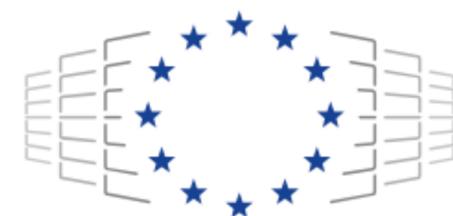
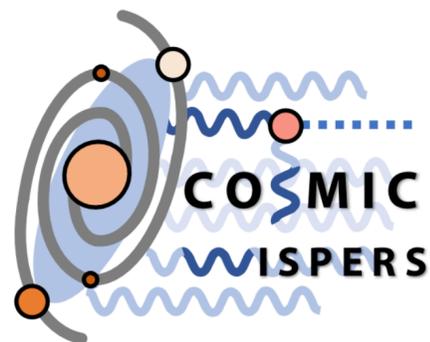
Dedicated to the memory of Carlo Guaraldo

## Introducing LaVA - Lattice Virtual Academy

Maria Paola Lombardo INFN Firenze



on behalf of the LaVA Group



**EuroHPC**  
Joint Undertaking

..in a nutshell, LaVA is a WEB site ....

← → ↻ <https://sites.google.com/view/lattice-virtual-academy/> M ⋮



**LaVA is a virtual platform for advanced e-learning in Lattice Field Theory**

# Why a Virtual Academy :

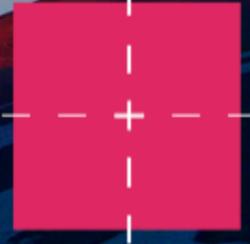
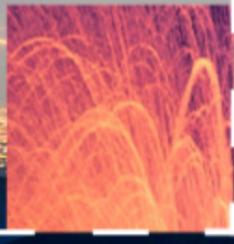
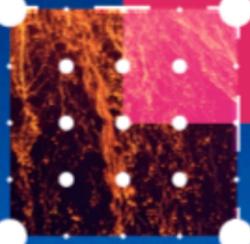
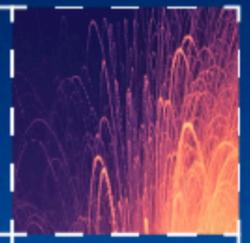
Training and Inclusivity

Easy reference for different communities

# Why Lattice Field Theory:

At the crossroads

of Hadron Physics, Computing, & More



# Lattice Field Theory

This week: talks by Gert Aarts “Hadrons under extreme conditions”

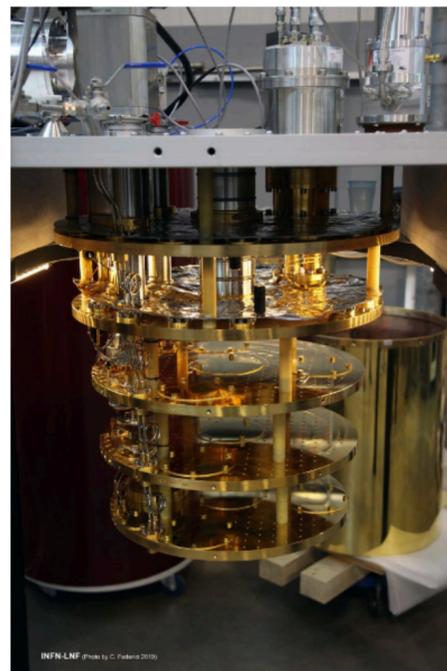
Mike Peardon “NA6-LatticeHadrons”

# Lattice at the crossroads: Axions as a case study

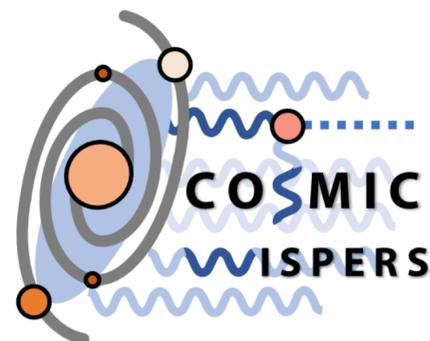
experimental searches@LNF

QUAX

*Wherever we go,  
we hear about axions!*



COST Action on  
Cosmic Wispers:



Claudio Gatti, LNF  
and MpL on the  
management comm

The Galileo Galilei Institute for Theoretical Physics  
Arcetri, Florence

**Axions across boundaries between Particle Physics, Astrophysics, Cosmology and forefront Detection Technologies**  
Apr 26, 2023 - Jun 09, 2023

The purpose of this workshop is to bring together scientists with different backgrounds and expertise to discuss open problems, recent developments and future directions in axion physics, a field that is notoriously replete with interdisciplinary connections. The aim is to foster a fruitful cross breeding between different theoretical areas, with a focus on certain open issues in axion particle physics, astrophysics and cosmology. From the experimental side, a blossoming of potentially game-changing ideas, with an exciting crossover from experimental particle physics to materials science and cutting-edge technologies is inspiring new methods for axion searches. The interaction between the experimental and theoretical communities will foster the merging of 'how to search' with 'where to search' into optimized strategies to hunt for the axion.

**Organizing Committee:**  
Gianpaolo Carosi, LLNL  
Kiwoon Choi, IBS, Daejeon, CTPU  
Luca Di Luzio, University of Padua and INFN  
Babette Dobrich, CERN  
Inma Dominguez, University of Granada  
Maurizio Giannotti, Barry University  
Igor Garcia Irastorza, University of Zaragoza  
Enrico Nardi, INFN - LNF  
Andreas Ringwald, DESY  
Pierre Sikivie, University of Florida  
Julia Vogel, LLNL & University of Zaragoza

**Topics and Schedule:**

- Training week (1st week)
- Axion astrophysics (2nd & 3rd weeks)
- Axion cosmology (3rd & 4th weeks)
- Axions in particle physics (4th & 5th weeks)
- Axion experiments (5th & 6th weeks)
- Conference week (7th week)

Contact persons: [enrico.nardi@lnf.infn.it](mailto:enrico.nardi@lnf.infn.it)

Axion theory:

GGI program

Coordinated

by Enrico Nardi, LNF

# Lattice at the crossroads: Axions as a case study

Details on the lattice role in QCD axion on the

‘QCD topology’ section

coordinated by C. Bonanno of

the Strong-2020 Nt-6 deliverable:



Progress in Particle and Nuclear Physics

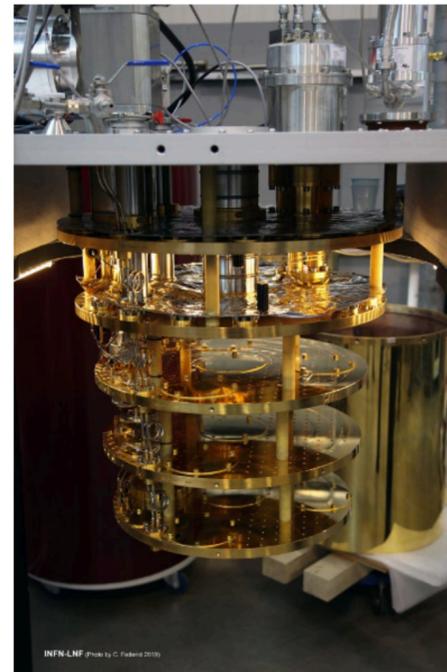
Volume 133, November 2023, 104070



Review

## Phase Transitions in Particle Physics: Results and Perspectives from Lattice Quantum Chromo-Dynamics

### QUAX



The Galileo Galilei Institute for Theoretical Physics  
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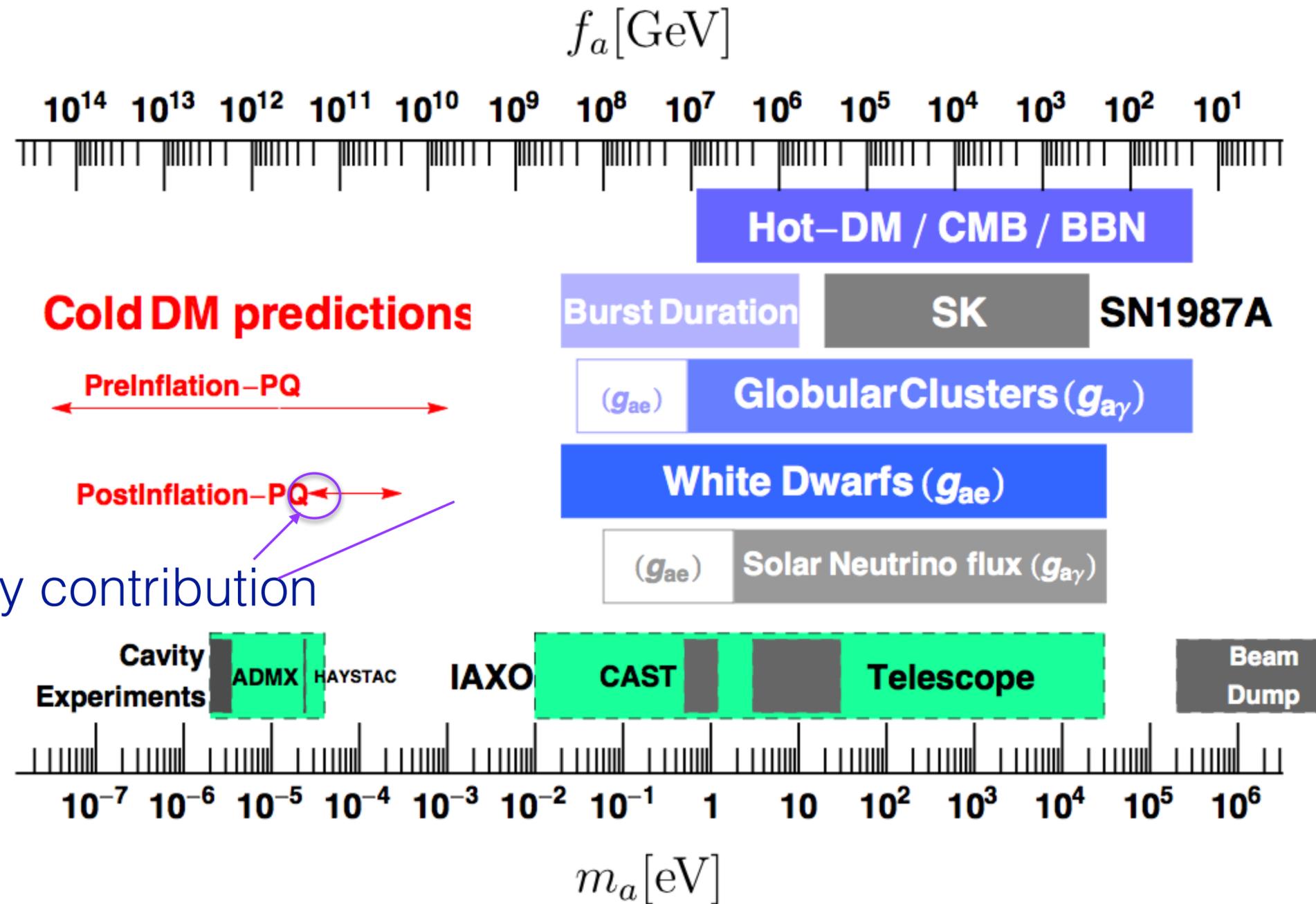
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# Lattice Field Theory and QCD axion



# Lattice Field Theory and QCD axion

$f_a [\text{GeV}]$



Hot-DM / CMB / BBN

**Cold DM predictions**

Burst Duration SK SN1987A

PreInflation-PQ

$(g_{ae})$  Globular Clusters  $(g_{a\gamma})$

PostInflation-PQ

White Dwarfs  $(g_{ae})$

$(g_{ae})$  Solar Neutrino flux  $(g_{a\gamma})$

Lattice topology contribution

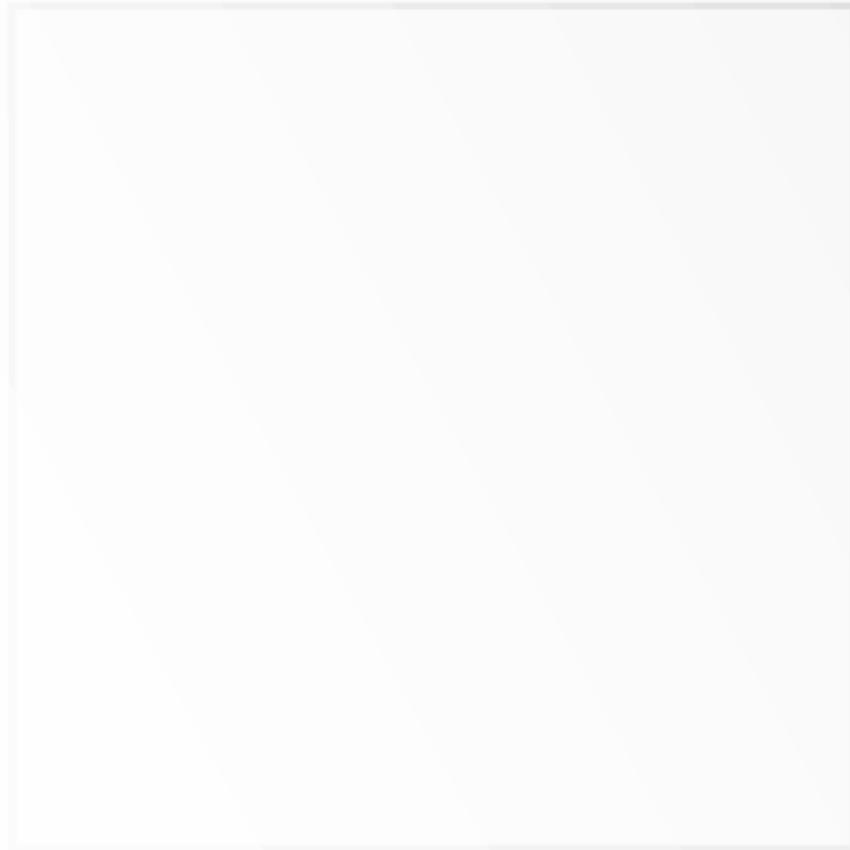
Cavity Experiments ADMX HAYSTAC IAXO CAST Telescope Beam Dump



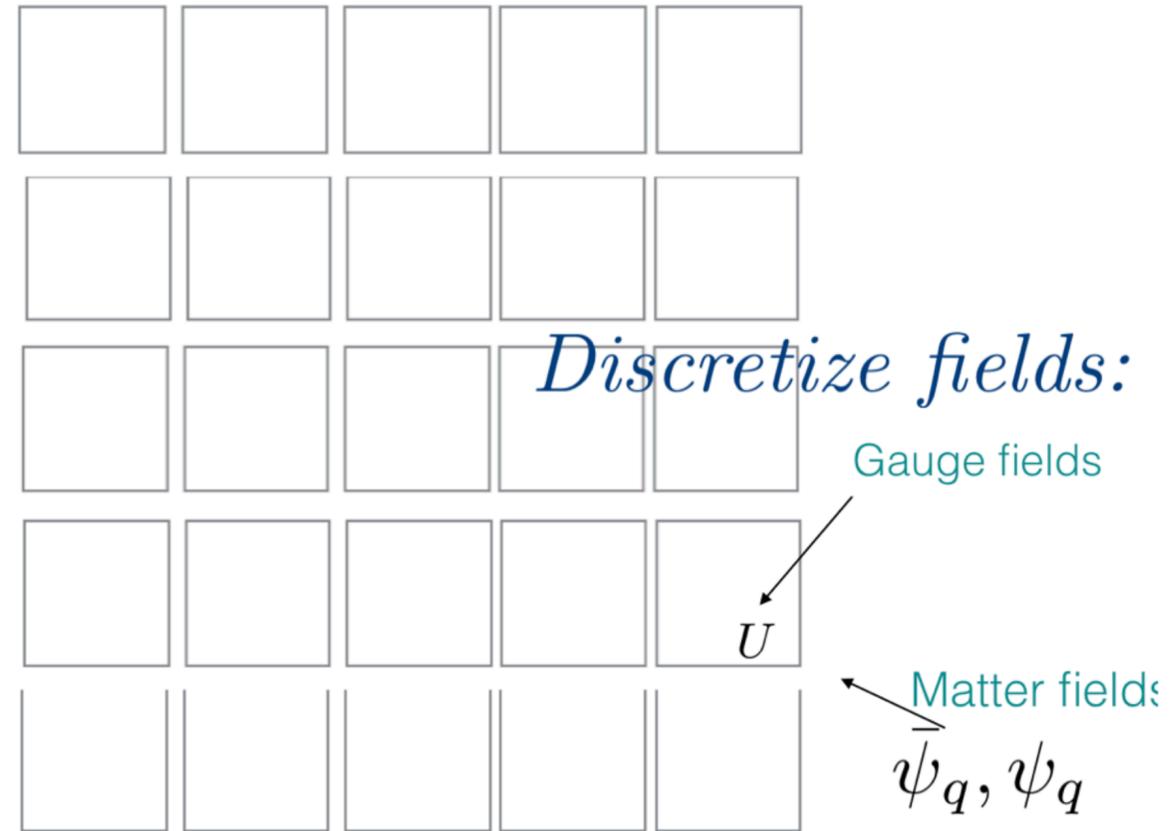
$m_a [\text{eV}]$

Placing these limits is highly non trivial:  
**Lattice Field Theory should be made accessible**

# Computing



## Lattice Gauge Theory



## Computational Strategy:

1) Rotation to imaginary time + discretisation

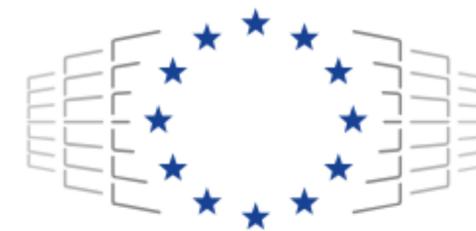
2) Monte Carlo Simulation

$$\langle 0 | \mathcal{O} | 0 \rangle = \frac{\sum_{\alpha} \mathcal{O}_{\alpha} e^{-S_{\alpha}}}{\sum_{\alpha} e^{-S_{\alpha}}}$$

# Computationally Expensive!!!

# The European landscape: EuroHPC

<https://eurohpc-ju.europa.eu/>



**EuroHPC**  
Joint Undertaking

## Leading the Way in European Supercomputing

EuroHPC JU is a joint initiative between the EU, European countries and private partners to develop a World Class Supercomputing Ecosystem in Europe.



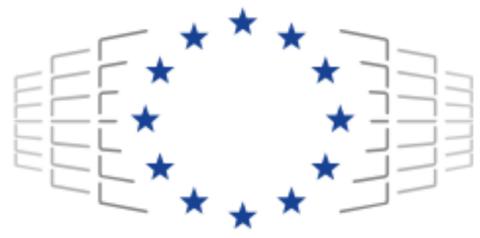
LUMI supercomputer  
CSC (Image credits: Fade Creative)



LEONARDO supercomputer  
Cineca



MareNostrum5 supercomputer  
BSC



**EuroHPC**  
Joint Undertaking

From the EuroHPC site

## Budget

The EuroHPC Joint Undertaking is jointly funded by its members with a budget of around EUR 7 billion for the period 2021-2027.

### Five domains:

Biochemistry, Bioinformatics, Life Sciences, Physiology and Medicine

Chemical Sciences and Materials, Solid State Physics

**Lattice** Computational Physics: Universe Sciences, Fundamental Constituents of Matter

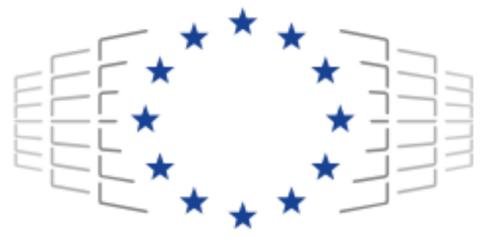
Earth System Sciences and Environmental Studies

Engineering, Mathematics and Computer Sciences



**EuroHPC**  
Joint Undertaking





**EuroHPC**  
Joint Undertaking

From the EuroHPC site

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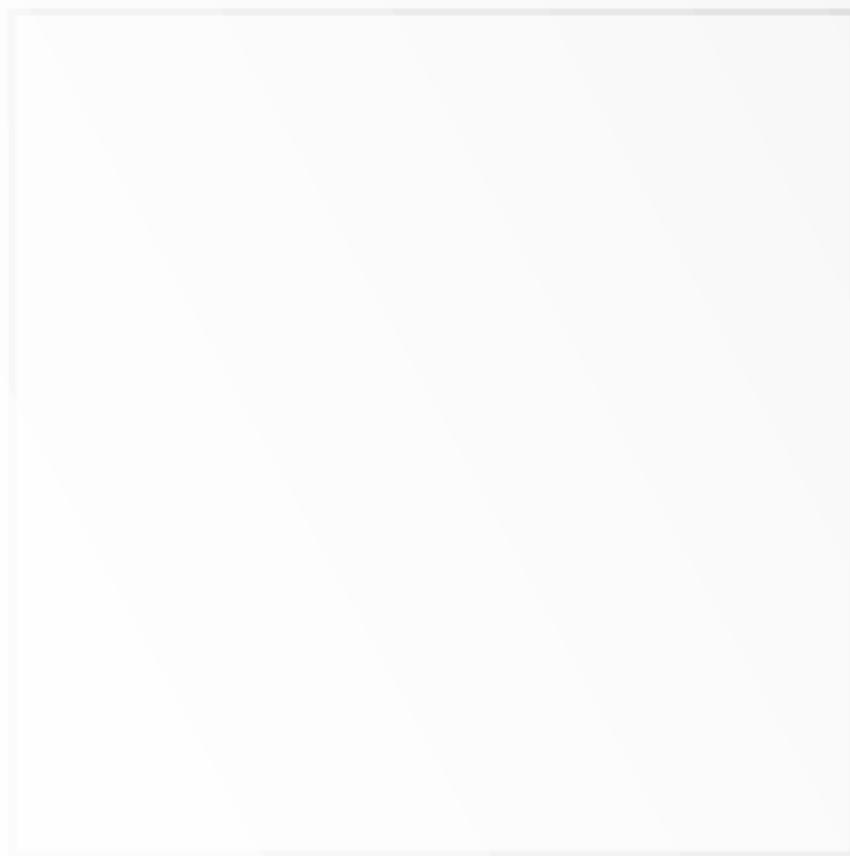
Engineering, Mathematics and Computer Sciences



**EuroHPC**  
Joint Undertaking

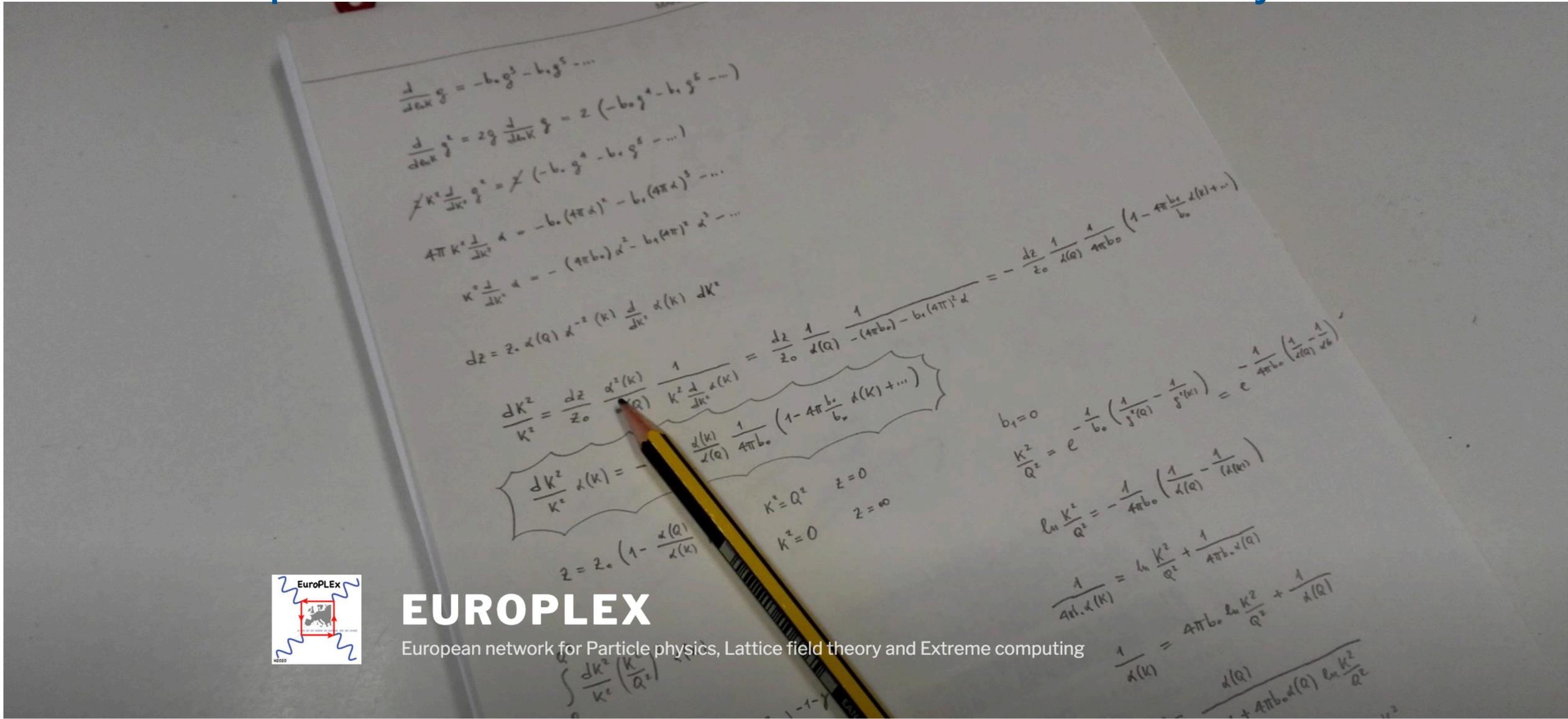
Different communities should know about Lattice:  
**Lattice Field Theory should be made accessible**

Training



Many excellent on-line resources available:

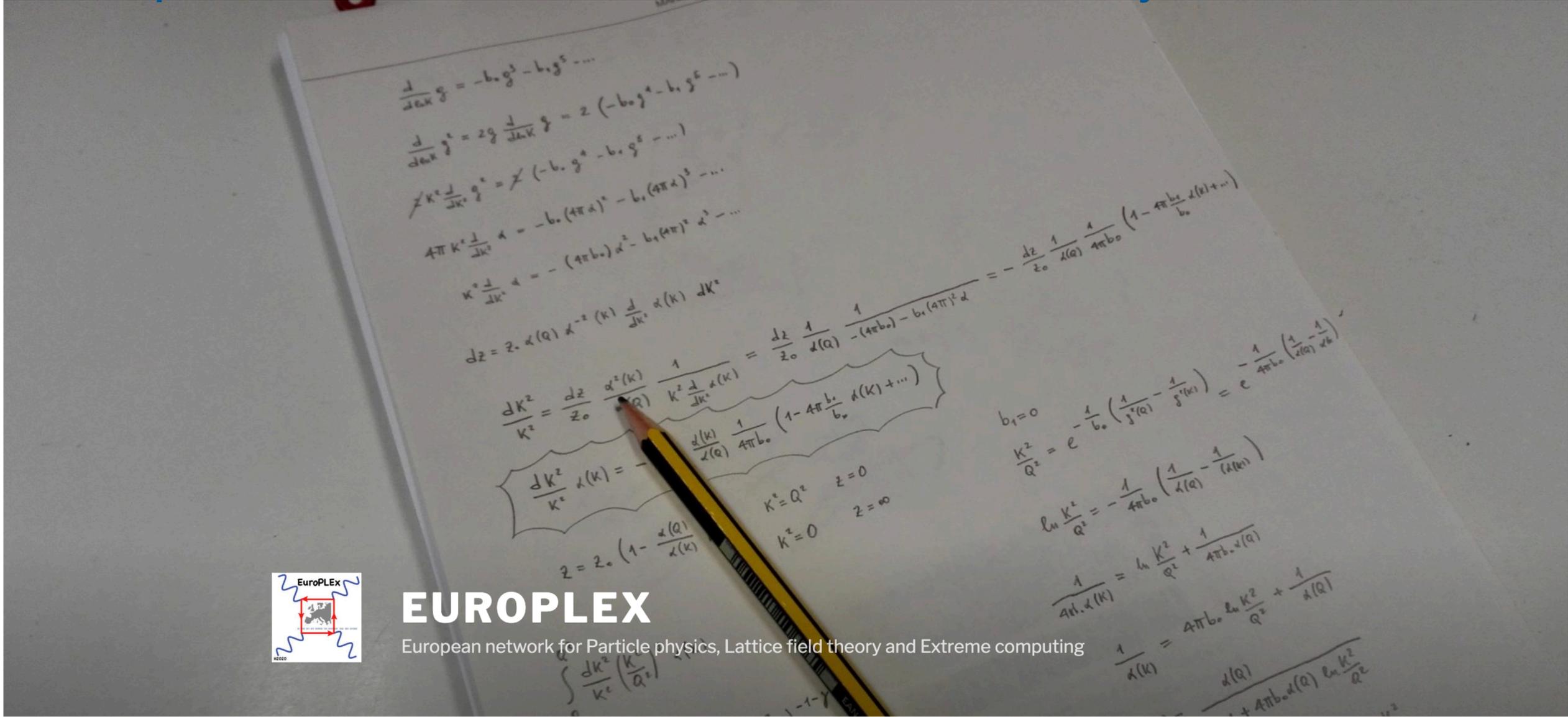
One example: Marie-Curie network coordinated by Francesco di Renzo



Many more examples of online schools during the pandemic

Many excellent on-line resources available:

Example: Marie-Curie network coordinated by Francesco di Renzo



**EUROPLEX**

European network for Particle physics, Lattice field theory and Extreme computing

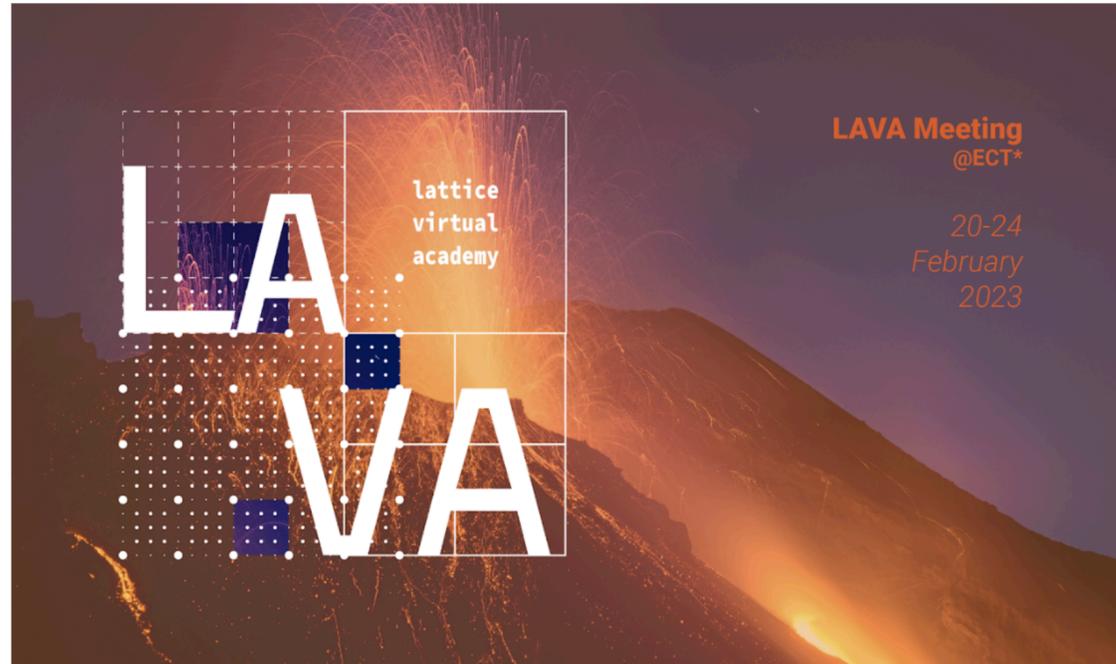
Excellent on-line resources on **Lattice Field Theory:**  
**They should be preserved and enhanced**



**LaVA is a virtual platform for advanced e-learning in Lattice Field Theory**

<https://sites.google.com/view/lattice-virtual-academy>

# Launching event: February 2023



## LaVA meeting @ECT\*

20 - 24 February, 2023

LaVA is a virtual platform for advanced e-learning and mixed learning in Lattice Field Theory and related areas which is under development within the Strong-2020 project and supported by FBK and by the INFN communication office. The first preparatory meeting took place from 20 to 24 February, 2023 at ECT\*. The webpage of the meeting can be found [here](#).

C. Bonanno

M. Peardon

MpL

Presentation to the community: July 2023

Plenary talk by C. Bonanno at Lattice 2023

<https://pos.sissa.it/453/109>

### Introducing the Lattice Virtual Academy (LaVA)

Speaker:

**CLAUDIO BONANNO**

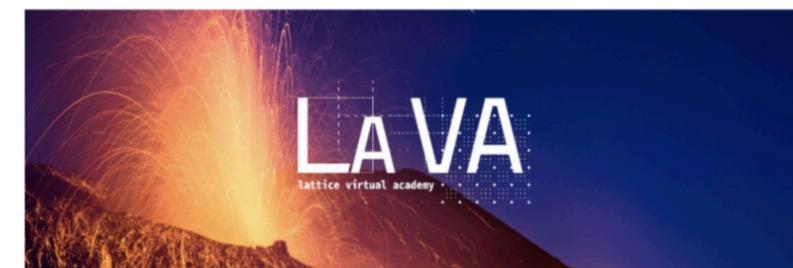
IFT UAM/CSIC MADRID

([claudio.bonanno@csic.es](mailto:claudio.bonanno@csic.es))

[On behalf of LaVA]

LATTICE 2023, 31/07/23

FERMILAB, BATAVIA, ILLINOIS, USA



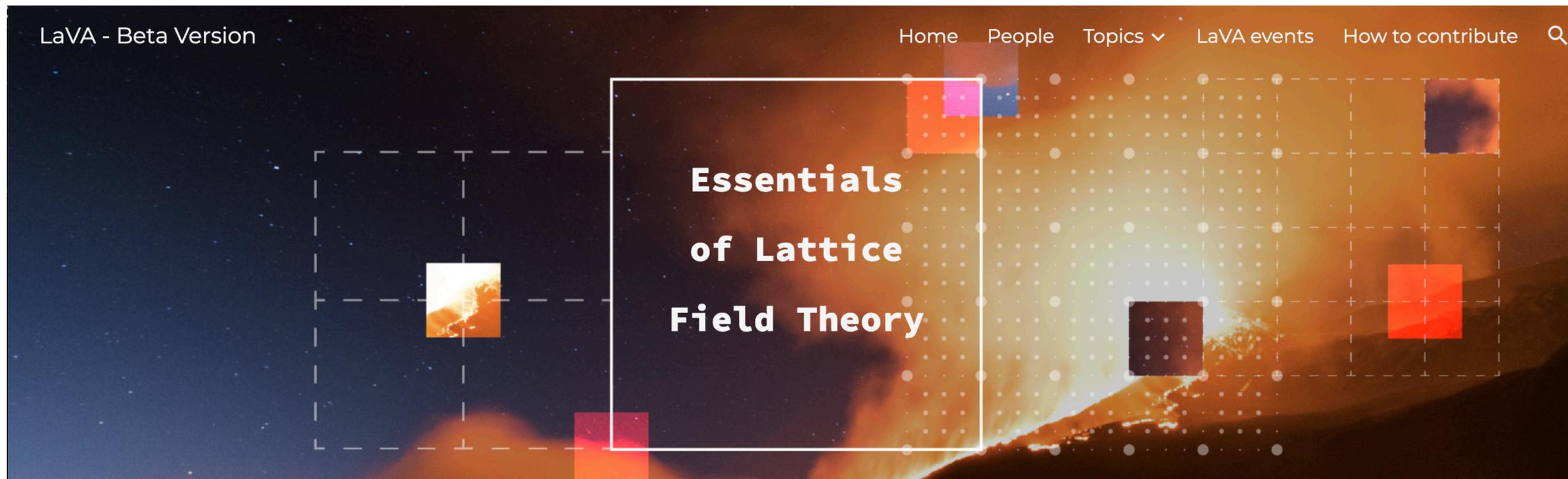
First completed set of Lectures on

# Essentials of Lattice Field Theories

by

Margarita-Garcia Perez, Christof Gatttringer, Simon Hands

Spring 2024



## Conveners

Margarita García Pérez, Instituto de Física Teórica UAM-CSIC  
Christof Gatttringer, Austrian Science Fund FWF & University of Graz  
Simon Hands, University of Liverpool

## Prototypical lecture:



### 8 Strong coupling expansion

- Strong coupling expansion
- Wilson loop / area law
- Glueballs
- Limitations of a strong coupling expansion

Slides

Modular structure, easy to keep up-to-date

What Next:

A home for LaVA



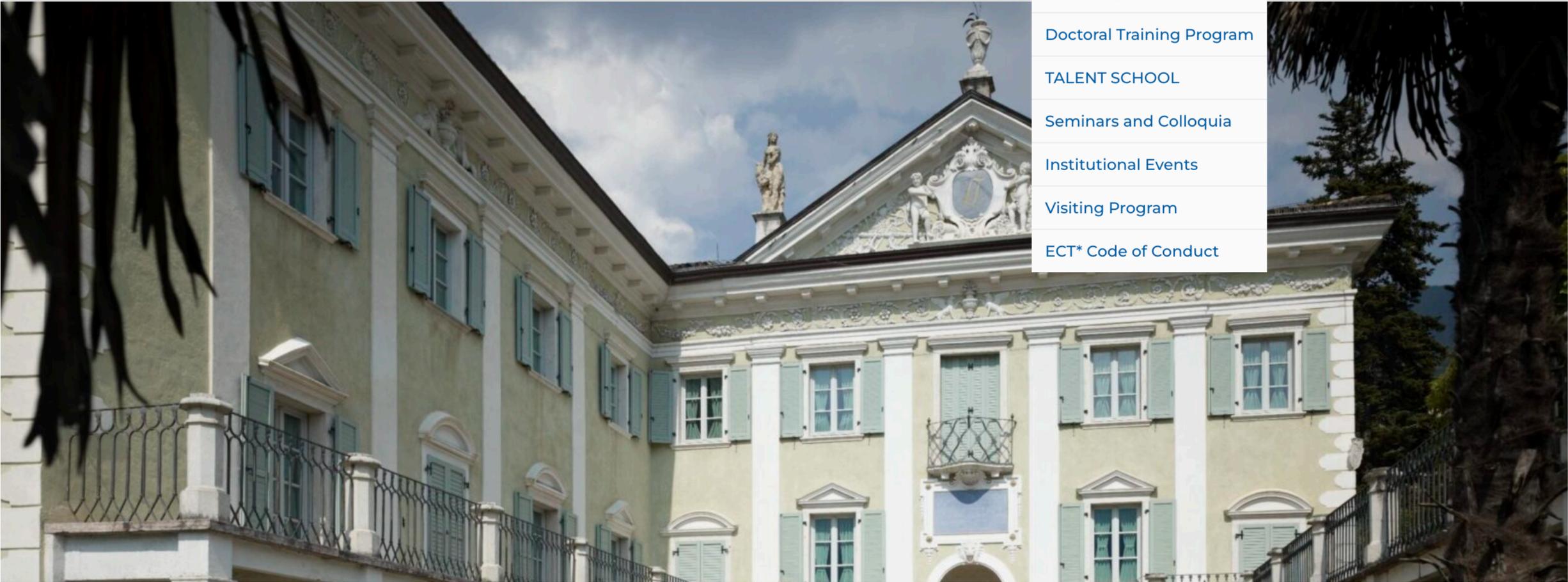
# A strong and successful ECT\* tradition in training:



[Fbk.eu](#) [Magazine](#) [Phonebook](#) [Job opening](#) [Canale YouTube](#) [Twitter](#)

[About Us](#) [External Funding](#) [Activities](#) [Research](#) [Outreach](#) [Publications](#) [People](#)

- [Workshops](#)
- [Doctoral Training Program](#)
- [TALENT SCHOOL](#)
- [Seminars and Colloquia](#)
- [Institutional Events](#)
- [Visiting Program](#)
- [ECT\\* Code of Conduct](#)



# A crucial support from the previous ECT\* Director GERT AARTS:



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### Internal organization:

Barbara Gazzoli, ECT\* - Project Assistant

Francesca Guerzoni, Petra Jansen - FBK - Web and Communication

*Many thanks!*

To be continued: ongoing discussions with the

incoming ECT\* Director Ubirajara Van Kolck

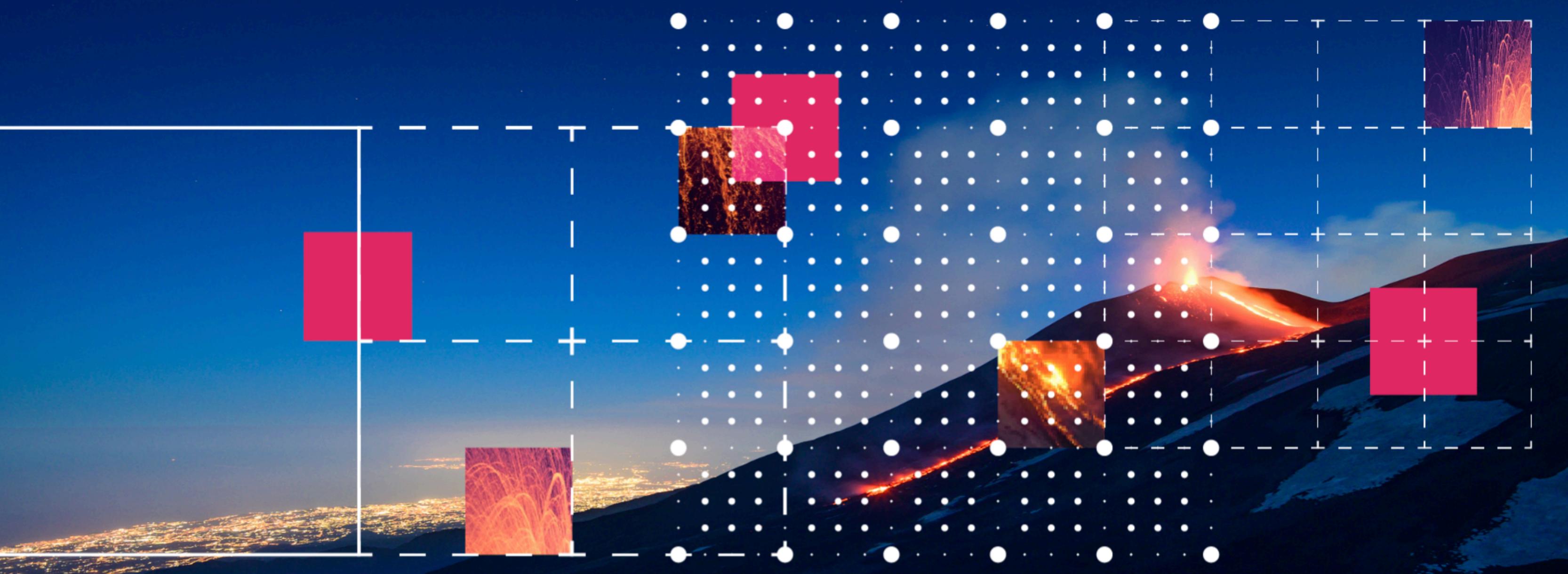
Goal: to make ECT\* the official home of LaVA

Please visit:

<https://sites.google.com/view/lattice-virtual-academy>

Contacts:

[lava@ectstar.eu](mailto:lava@ectstar.eu)



*Thanks!*