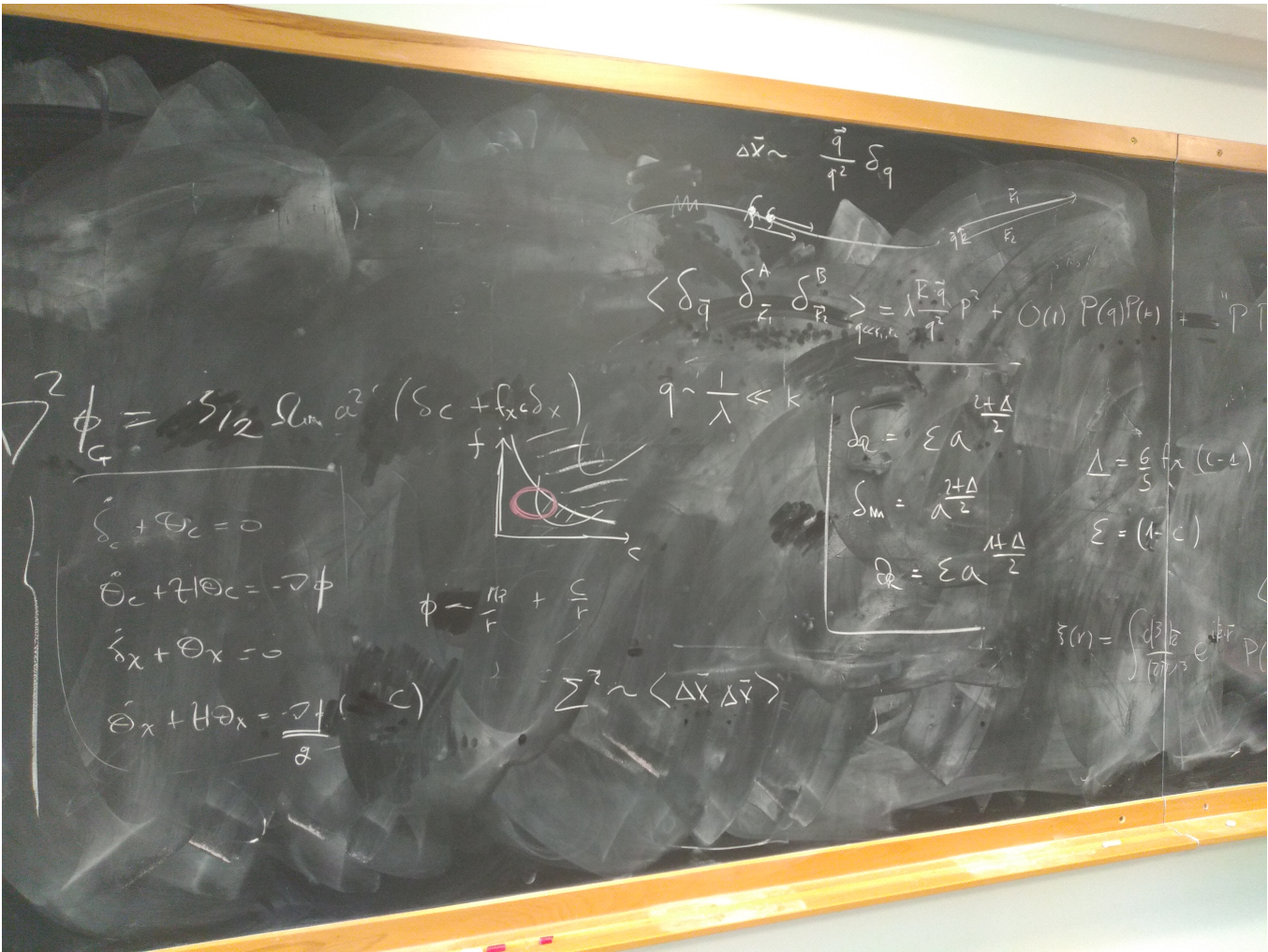


# New physics with Galaxy clustering (the series)

Emanuele Castorina  
University of Milan

With big thanks to Ennio Salvioni, Diego Redigolo, Marko Simonovic, Azadeh Moradinezhad Dizgah, Emilio Bellini, Vera Gluscevic, Guido D'Amico, Massimo Pietroni, Tomer Volansky and Anze Slosar

# How it started, ~ Feb 2020



Almost everything on this blackboard turned out to be wrong

# How it's going

## The Galileo Galilei Institute For Theoretical Physics

Centro Nazionale di Studi Avanzati dell'Istituto Nazionale di Fisica Nucleare

Arcetri, Firenze



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### Event at Galileo Galilei Institute

#### Workshop

#### New Physics from Galaxy Clustering at GGI

Aug 25, 2025 - Oct 03, 2025

**Apply** (deadline: May 31, 2025 )

#### Abstract

This workshop aims at catalyzing the joint efforts of particle physicists and cosmologists towards the exploration of new physics with large cosmological datasets. The workshop is structured to encompass three thematic weeks dedicated to model building and testing fundamental physics in cosmology, developing novel theoretical tools to search for new physics in cosmological observables, and discussing the potential of next generation experiments to probe the plethora of new physics signals. A symposium with summary talks will conclude the workshop. A concurrent school is planned, with the aim of addressing the evolving landscape of this new field and helping participants catch up with recent developments and novel tools. An important feature of the workshop is a designated focus week, devoted to the initiation of a much-needed community white paper, summarizing the new and well-motivated particle physics models that can be tested in cosmology in the light of upcoming data and planned future experiments. The workshop nicely aligns with the expected data releases from DESI and Euclid.

#### Topics

**Week 1: School on modeling of LSS observables and dark sector model building**

**Week 2: Models of new physics vs cosmological probes**

**Week 3: Theoretical tools to search for new physics**

**Week 4: Focus week**

**Week 5: Design of the next generation of experiments**

**Week 6: Conference**

A six weeks program in 2025 !

# The journey so far



- New Physics with Galaxy Clustering 1, Nov 22 @ CERN
- New Physics with Galaxy Clustering 2, Nov 23 @ ICTP/IFPU
- New Physics with Galaxy Clustering 3, Nov 24 in Parma
- New Physics from Galaxy Clustering at GGI, Aug 25th to Oct 3rd, 2025

## New Physics from Galaxy Clustering

Nov 21 – 25, 2022  
CERN  
Europe/Zurich timezone



Overview

Timetable

Contribution List

Participant List

TH workshop secretariat

✉ [thworkshops.secretariat...](mailto:thworkshops.secretariat...)

Recent progress in theoretical modelling of galaxy clustering has led to new types of data analyses which are particularly important for constraining extensions of the  $\Lambda$ CDM cosmological model. This allowed for novel tests of new physics, both in the early and late universe. As a proof of concept, these new techniques have been applied to currently existing data to put the tightest constraints on several interesting scenarios, including early dark energy, ultralight axion dark matter, massive but light relics, decaying dark matter, interactions in the dark sector etc.

However, the landscape of possible BSM models which can be tested using galaxy clustering remains largely unexplored. This is a massive opportunity for the BSM and cosmology communities to work together towards creating new ideas and deriving their phenomenological implications, as well as thinking about new observables and tests to be performed in the data. The main goal of this TH Institute is to bring the two communities together and initiate the discussion about possible types of new physics that can be tested using galaxy clustering. This is very timely, given the large amount of new data that will be available in the next several years, as well as ever more ambitious observational programs already planned for the following decade.

The EFT of LSS gives a calculable model.

Modifying it *consistently* in the presence of new physics gives to cosmology the possibility to *discover* new physics in precision data.

# What New Physics?

Most new dynamics at  $z > 10$  does not require any modification to existing LSS codes

- Interactions of DM with baryons;
- Interactions of DM with DR à la ETHOS/Buen-Abad+15;
- Early Dark Energy ;
- Neutrinos self-interactions in the context of the  $H_0$  tension ;
- Particle physics inspired solutions to  $H_0$  and  $S_8$  tensions;
- ....

Anything that can be summarized in an early Universe Transfer function  $T(k)$  can already be constrained !

# New Physics $\neq$ Early Universe

Nightmare Scenarios : The Dark Sector is actually Dark

Visible sector

15% of matter

$$g_N = \sqrt{m_\chi m_p} / M_{\text{Pl}}$$

**Dark Sector, 85 % of matter**

- DM Mass
- Couplings
- Other particles...

New physics in the Dark Sector can affect dynamics at *any* times (it **requires** EFT)

- Light but massive relics and ultra-light axions;
- Late time interactions in the DS, e.g. long range forces;
- Decaying DM;
- ...

# The five stages of grief

Me : This new BSM model is so cool ! How about some LSS constraints ?

Also me :

- 1) **Denial** : I'm never going to redo all the calculation I did for the standard model.  
There has to be a way out !
- 2) **Anger** : What's wrong with these people !
- 3) **Bargaining** : Can I get away with only 1/2 of the calculations and wave my hands for the rest?
- 4) **Depression** : I'm never going to do it. It's  $\Lambda$ CDM all the way.
- 5) **Acceptance** : Alright, I'll do it.

Looking for new physics with the LSS is hard, but it is a *unique* window into the many open questions of the cosmological model



# The EFT of New Physics

$$\delta^{(n)}(\mathbf{k}) \sim D^{(n)}(\tau) \int_{\mathbf{q}_1 \dots \mathbf{q}_n} \delta_D[\mathbf{k} - (\mathbf{q}_1 + \dots + \mathbf{q}_n)] F_n(\mathbf{q}_1, \dots, \mathbf{q}_n) \delta(\mathbf{q}_1) \dots \delta(\mathbf{q}_n)$$

In the presence of New Physics:

- The ansatz above might not work in the first place. The theory has a spatial scale.
- The n-th order growth factor is not simple

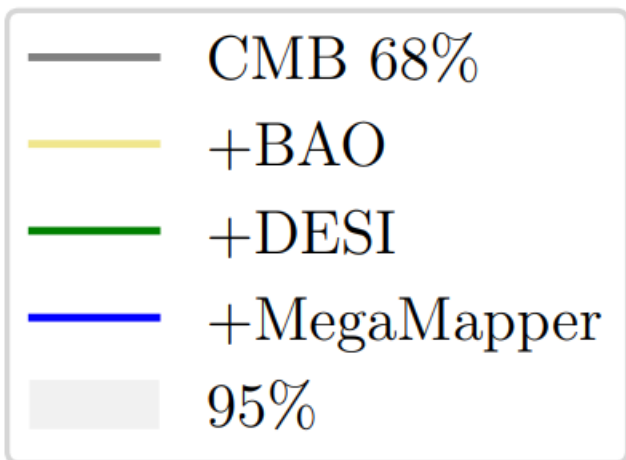
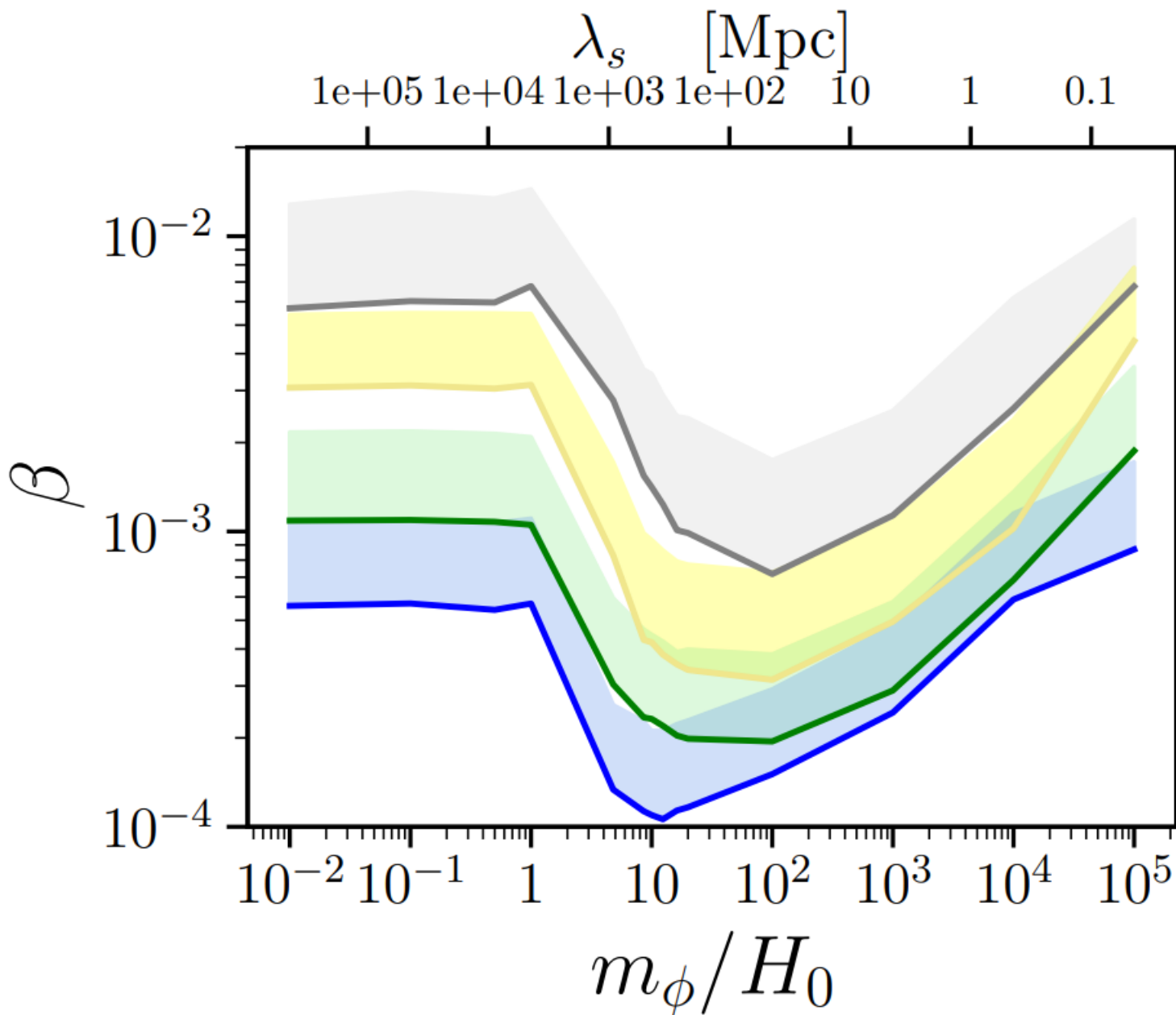
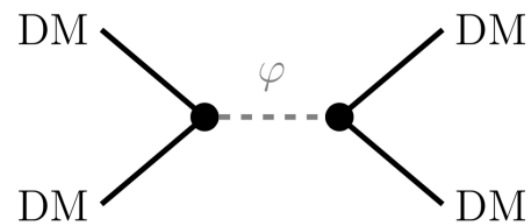
$$D^{(n)}(\tau) \sim [D^{(1)}(\tau)]^n$$

The theory has a new time scale.

- The structure of the kernels is different, new counterterms are possible

$$F_n^{(m)} \sim F_n^{\Lambda\text{CDM}} + \varepsilon \Delta F_n$$

# An example: long range dark fifth forces



- Down to 100 kpc
- Cannot extend to lower masses because of lack of EFT model
- Fraction in the works

Wed @1:15pm

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- Interplay between large and small scales, e.g. fractions.

Small signal and small theory errors vs large signal and large theory sys.

## New Physics from Galaxy Clustering III

Nov 4 – 8, 2024

Centro Congressi S. Elisabetta, Parma

Europe/Rome timezone



Overview

Participant List

Travel Information

Accommodation

Contact

 [E.Salvioni@sussex.ac.uk](mailto:E.Salvioni@sussex.ac.uk)

Recent progress in theoretical modeling of galaxy clustering has led to new types of data analyses, which are particularly important for constraining extensions of the  $\Lambda$ CDM cosmological model. However, the landscape of the possible signatures that can be tested using Large Scale Structure observations, including the ongoing DESI and Euclid surveys, remains largely unexplored.

Building on the success of the previous installments

- at IFPU Trieste in 2023: <https://indico.cern.ch/event/1308028/>,
- at CERN in 2022: <https://indico.cern.ch/event/1192722/>,

the goal of this workshop is to bring together the cosmology and particle theory communities, to discuss current and future opportunities to probe fundamental physics using galaxy clustering.

The workshop will be held at the University of Parma. The program will be designed to facilitate interaction, with a limited number of talks accompanied by discussion sessions and ample free time for exchange.

The meeting will start on Monday, November 4, 2024, and end on Friday, November 8.

Save the date and stay tuned for an invitation !

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3) Theoretical tools to search for new physics

What new theoretical tools are needed for testing new physics with LSS data?  
What role can numerical simulations play? What is the  
interplay between the LSS and astrophysical searches for new physics?

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Identify the short and in the long term goals of this program

Coordinate the preparation of a white paper presenting a range of new science cases for ongoing and future galaxy survey.

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## 6) Symposium

More traditional conference-like workshop

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# Outlook

New physics in the Dark Sector, at late or early times, should be a primary science case of current and future surveys.

Making this happening requires the combined effort of two communities.

We hope the 'New Physics' series and this meeting will help towards this goal

See you in Parma (2024)  
and Florence (2025) !

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**Thanks!**