Community white paper:
New physics from galaxy surveys

conclusions from this workshop
and the road ahead

New Physics from Galaxy Clustering at GGI

Sep 29, 2025 - Oct 03, 2025

New physics from galaxy clustering III, at the University of Parma
New physics from galaxy clustering II, at IFPU, Trieste
New physics from galaxy clustering, at CERN

Bring cosmologists and particle physicists together

What are the opportunities for new physics in LSS data?

How to optimally search for new physics in the data?

What are good new science cases for future surveys?

Can any of this impact the design of future telescopes?


Why are we doing this?!

There was a lot of progress in the last ~5 years

(new models, new ideas, new developments in theory and data analysis)

We have a critical mass to articulate these ideas
and present them to the broader community

Consensus in the last 6 weeks:
it would be nice to write a short community paper

What are the main messages of this document?

There will be a lot of new data that will constrain strongly new physics scenarios

(what are the relevant new data, what range of scales they probe, what is the precision etc.)

There is a lot of new physics cases that LSS can probe, largely unexplored

(we do not want to list all models, but to give some general overview)

For whom are we writing it?

For particle physics community, to inspire more people to explore BSM in LSS

Also for cosmologists, to understand better BSM opportunities in LSS

For collaborations, to adjust current pipelines and design of future surveys

Content:

Overview of data, current and future

Overview of analyses, PT, P(k), n-point, field-level, SBI

Classes of new physics models

How to organize this? According to signatures? Observables? Early/late universe?

Cover all examples done so far and perhaps discuss new ones?

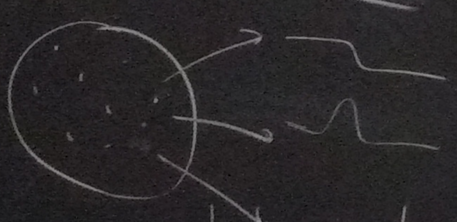
Curvature, neutrino masses, primordial NG, dark energy, light but massive relics, ultralight axion, multiple DM components, new long-range forces in the dark sector, variation of fundamental constants, modifications of pre-recombination expansion history, early dark energy, self-interacting DM, DM-baryon interactions, late-universe DM phase transitions…

1) Context (LSS $\gtrsim$ 1 Mpc)

2) Data and relevant scales and errors

$\Downarrow$

4) Alternative view $\quad k_* > k_{NL}(z)$



→ ULA, WDM, IC, Late

Main signatures

3) Provide some classes of models

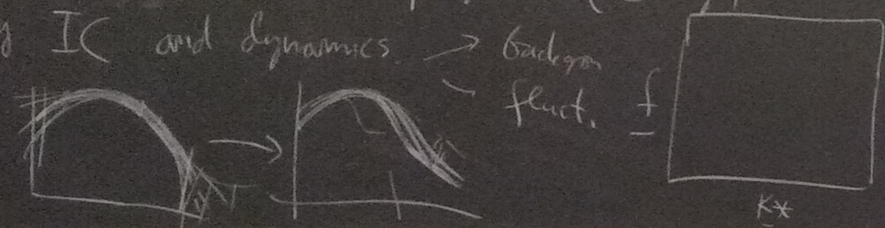
- Only late time + secondary CMB. → clustering DE plus trans. decaying DM
- Modifies only IC ($z = z_{rec}$) $\quad m_{DM}(z)$

DAO, features, f_{NL}, ICs from inflation

Recombination new-physics (early)

- Modify IC and dynamics. → background fluct. f

~~EP~~



k_*

- Light but massive particles ← QCD axion

f_{DM} is warm

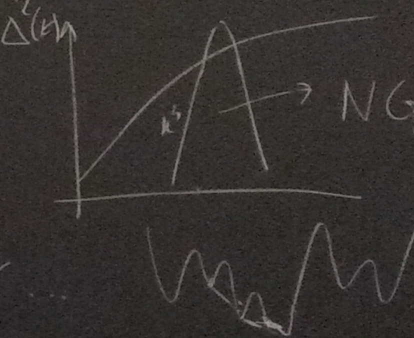
- Ultra-light axion f_{DM}
- DM interacting with baryons
- DM-DR
- Long-range forces in DM
- Decaying DM

- $m_{DM}(z)$
- EDE
- Clustering DE
- Non-SM neutrinos
- DAO + features.

- Late-universe phase transitions.

ISW, bump $\Delta^2(k)$

- ~~LI~~, ~~EP~~
- ICs, f_{NL}, parity, cosmo collider ...
- Modified recombination.
- Curvature + Anomalies on large scales } Do we see the "beginning" of inflation



$\Omega_K < 0$

Some open questions

Are there interesting targets?

We can test minimal CDM on cosmological scales up to ~1%

Examples: $f_{\rm NL} \sim 1$, $\Delta N_{\rm eff} \approx 0.027$ or neutrinos ~5%

Hui, Ostriker, Tremaine, Witten (2016)

$$\Omega_a \sim 0.001 \left(\frac{f}{10^{17}\,\mathrm{GeV}}\right)^2 \left(\frac{m_a}{10^{-26}\,\mathrm{eV}}\right)^{1/2}$$

if it has the decay constant close to $M_{\rm pl}$…

if there is an ULA that can be probed on cosmological scales…

Some open questions

How to bridge the gap theory-observations?

Can we do some simplified analyses? Are they good enough?

Example: $f\sigma_8$ + BAO

Simple templates in P(k) (linear or nonlinear?) with k_* and $f_{\rm new\ DM}$

Bandpower reconstruction of the linear matter power spectrum

Issues: early vs late, background vs fluctuations, dynamics vs ICs

Some open questions

If we use PT based analyses, what should we do with the priors?

Prior volume effects

(Small in LCDM and usual analysis, more important for beyond LCDM, for example in w0-wa)

Perturbativity priors

(Are we being consistent when using PT? How to ensure this? Can this fix prior volume effects? This becomes a problem for higher loop computations, for example 1-loop B)

HOD-based priors

(How to combine simulations and PT? Is this general enough for new physics?)

What are the next steps?

After the conference, we will send the information about the white paper and how to proceed

Any comments? Ideas? Suggestions?