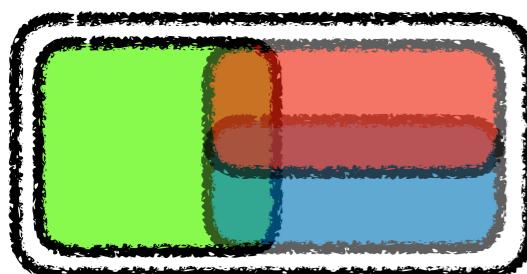


# *New avenues and observational constraints of functors of actions !*

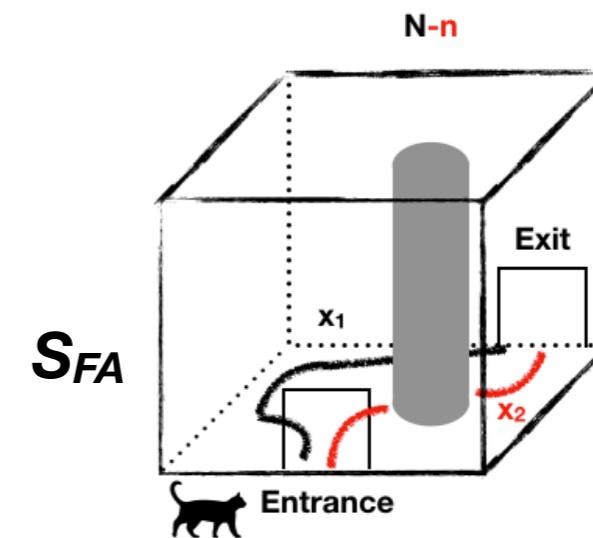
Pierros Ntelis, Independent Researcher  
at Aix-Marseille University

NEB-20 Conference of Recent Developments in Gravity organised by  
Hellenic Society for Relativity, Gravitation and Cosmology ([HSRGC](#))

PN and A.Morris, Functors of Actions  
Foundation of Physics Journal '23 (2010.06707)



PN A  $(Dt, Dx)$ -manifold with  
N-correlators of Nt-objects,  
under review (2209.07472)



## **Outline of the talk**

**What is built by theoretical cosmologists ?**

**Functors of Actions (FA)**

**A guide to build models of FA**

**Actionic field fluctuations  
(Simulated constraints)**

**A  $(Dt, Dx)$ -manifold with NPCF of Nt-objects**

**General formalism w/ and w/o contaminants**

**Application to LSS ( applied also to QFT )**

**Conclusion and Outlook**

# Cosmological Gravitology

Functors  
of  
Actions  
 $S_{FA}$

General  
Relativity  
unique theory of  
massless  $g_{\mu\nu}$

Massive  
Gravity  
 $m_g > 0$

Tensor  
 $T_{\mu\nu}$

Vector  $V_\mu$

Additional  
Field

Scalar  
 $\phi$

Hordenski

Quint-  
essence

Brans-  
Dicke

$f(R)$

KGB

Galileon

Galileon  
UDEDM

Gauss-  
Bonnet

Love-  
lock

Break  
Assumptions

Isotropy  
homogeneity

Extra  
Dimensions

locality

$$S = \int_V d^D x \mathcal{L}$$

## Functor of actions ( $S_{FA}$ ) theories

Functor (F) is the generalisation concept of functionals

Functionals is the generalisation concept of functions

Action (S) in physics is a quantity which is the product of energy with time.

Action is a quantity which tell us the amount of possible ways a particle can travel from one point to another within a certain region

Functor of actions predict the existence of actionic fluctuations and field-particles which is an analogue of the energetic/topological fluctuations/field-particles in nature.

$$S_{FA} \supset \int_{\Omega_S} dS' \supset S_{EFT} \supset \int_{\Omega_S} dS' S' \quad \xleftarrow{\text{blue arrow}} \quad S = \int_V d^D x \mathcal{L}$$

# Functors of actions

Limits we can get from these theories are  
GR, Hordenski, Inflation, EFTofLSS, Strings, ...

Example:

$$\begin{aligned} \mathcal{S}_{\text{FA}} &\ni \int_{\Omega_S} dS' \rightarrow \int_0^S dS' \xrightarrow{\text{GR limit}} \int_0^{S_{\text{GR}}} dS' = \sum_{i=1,2} S_i = S_R + S_m \\ &= c^4 \int \sqrt{-g} \frac{R}{16\pi G_N} d^4x + c^4 \int \sqrt{-g} \mathcal{L}_m(g_{\mu\nu}) d^4x, \\ S_{\text{GR}} &\equiv c^4 \int \sqrt{-g} \left[ \frac{R}{16\pi G_N} + \mathcal{L}_m(g_{\mu\nu}) \right] d^4x. \end{aligned}$$

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# Functors of actions

## 8. Strings limits

Polyakov<sup>54</sup> has studied the action of string-theory dynamics<sup>12,22</sup> and successfully quantized string theory. Here we show that FA is also reduced to the one of the actions of string theory, simply as:

$$\mathcal{S}_{\text{FA}} \ni \int_0^S dS' \xrightarrow{\text{Strings limit}} \int_0^{S_{\text{string}}} dS' = S_{\text{string}} = \frac{T}{2} \int d^2\sigma \sqrt{-h} h^{ab} g_{\mu\nu}(x) \partial_a x^\mu(\sigma) \partial_b x^\nu(\sigma), \quad (40)$$

where  $T$  is the string tension,  $g_{\mu\nu}$  is the metric of any targeted manifold of a D-dimensional space and  $x_\mu(\sigma)$  is the coordinate of the targeted manifold. Moreover,  $h_{ab}$  is the worldsheet metric, ( $h^{ab}$  is its inverse), and  $h$  is, as usual, the determinant of  $h_{ab}$ . The signatures of the metrics are chosen so that the timelike directions are positive while the spacelike directions are negative. The spacelike coordinate is denoted with  $\sigma$ , while the timelike coordinate is denoted with  $\tau$ .

P.Ntelis and A.Morris (2023)

# Functors of actions

## Prediction of Modification of Einstein Field Equations

$$S_{\text{EFT}}^{\text{Simplified},2,\text{GR},2} = \beta^{(S_R)} S_R + \alpha^{(S_m)} + S_m + S'_3$$

**Prediction of Actionic fields  
(similar to energy fields)**

$$0 = \delta S_{\text{EFT}}^{\text{Simplified},2,\text{GR},2}$$

$$0 = \int d^4x \sqrt{-g} \delta g^{\mu\nu} \left( \beta^{(S_R)} \frac{c^4}{16\pi G_N} \left( R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} + \Lambda g_{\mu\nu} \right) - T_{\mu\nu}/2 \right) + \delta S'_3$$

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{1}{\beta^{(S_R)}} \frac{8\pi G_N}{c^4} \left( T_{\mu\nu} + \delta [\mathcal{L}_3]_{\mu\nu} \right)$$

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# Functors of actions

## Constraints and Prediction of Modification of EFE

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{1}{\beta(S_R)} \frac{8\pi G_N}{c^4} \left( T_{\mu\nu} + \delta [\mathcal{L}_3]_{\mu\nu} \right)$$

**Prediction of Actionic fields,  
by choosing a special Lagrangian fluctuation**

$$\delta [\mathcal{L}_3]_{\mu\nu} \rightarrow \delta \mathcal{L}_3 \begin{pmatrix} \rho & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

**Equation of state**

$$w = - (1 + \delta \mathcal{L}_3)^{-1}$$

$$T_{\mu\nu}^{(2)} = \begin{pmatrix} \rho(1 + \delta \mathcal{L}_3) & 0 & 0 & 0 \\ 0 & -P & 0 & 0 \\ 0 & 0 & -P & 0 \\ 0 & 0 & 0 & -P \end{pmatrix}$$

for  $w \sim -0.9$

=>

$\delta \mathcal{L}_3 \sim 0.1$

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# Functors of actions

## Constraints and Prediction of Modification of EFE

$$S_{\text{EFT}}^{\text{Quadratic}} = S_R + \beta S_R^2 + S_m$$

**Stationary  
Action  
Principle**

$$\begin{aligned} 0 &= \delta S_{\text{EFT}}^{\text{Quadratic}} \\ &= \delta S_R + \beta \delta (S_R^2) + \delta S_m \end{aligned}$$

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = \left[ 1 + \beta \int d^4x \sqrt{-g} \left( \frac{c^4}{8\pi G_N} R \right) \right]^{-1} \frac{8\pi G_N}{c^4} T_{\mu\nu}$$

$$G_{\text{eff}} = G_N \left[ 1 + \beta \int d^4x \sqrt{-g} \left( \frac{c^4}{8\pi G_N} R \right) \right]^{-1}$$

**Modification  
of  $G_{\text{eff}}$**

P.Ntelis and A.Morris (2023)

## 10. Current universe limit

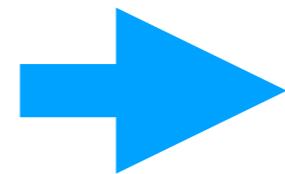
Note that since FA contains all possible actions, then ones that we have studied, as well as the exotic ones that we have not discovered yet,  $\Omega_S^{KE}$ , then the full action which describes the universe as a whole,  $S_{FA,U}$ , which will be constructed via a space of actions of the whole universe,  $\Omega_S^U = \{-\alpha_{exotic}S_{exotic}, \dots, \alpha_H S_H\}$ , assuming that the universe at very large scales is described by the healthy Hordenksi theories. The universe would be described by an action which is given by the actual action which describes the universe at the very large scales and high energies to the very small scales and low energies. Therefore it will include actions such as the Hordenski action,  $S_H$ , as well as an exotic action,  $S_{exotic}$ . These will be the limit of the action describing the whole universe which will include the reduced Hordenski action as defined earlier,  $S_{H(2-5)}$ , the action of the total matter of the universe,  $S_m$ , which includes basically the actions of the dark matter particles,  $S_{cdm}$ , and the actions of individual galaxies at smaller scales,  $S_g$ . The total action will also include the actions of black hole systems,  $S_{BH}$ , actions of neutron star systems,  $S_{NS}$ , actions of gravitational wave sources,  $S_{GWS}$ , actions of leptons, quarks, bosons, gluons, namely the action of the standard model particles,  $S_{smp}$ , the action of the Higgs,  $S_{m,Higgs}$ , the strings action,  $S_{strings}$ , as well as some exotic system that we have not discovered yet. Therefore we can write,

$$S_{FA} \ni S_{KE} = \int_{\Omega_S^{KE}} dS' = S_{FA,U} = \int_{\Omega_S^U} dS' = \int_{-\alpha_{exotic}S_{exotic}}^{\alpha_H S_H} dS' = \alpha_H S_H + \alpha_{exotic} S_{exotic} \quad (43)$$

$$\begin{aligned} S_{FA,U} = & \alpha_{H(2-5)} S_{H(2-5)} + \sum_{cdm=1}^{\infty} \alpha_{cdm} S_{cdm} + \sum_{g=1}^{\infty} \alpha_g S_g \\ & + \sum_{BH=1}^{\infty} \alpha_{BH} S_{BH} + \sum_{NS=1}^{\infty} \alpha_{NS} S_{NS} + \sum_{GWS=1}^{\infty} \alpha_{GWS} S_{GWS} \\ & + \alpha_{smp} S_{smp} + \alpha_{m,Higgs} S_{m,Higgs} + \alpha_{strings} S_{strings} + \alpha_{exotic} S_{exotic} \end{aligned} \quad (44)$$

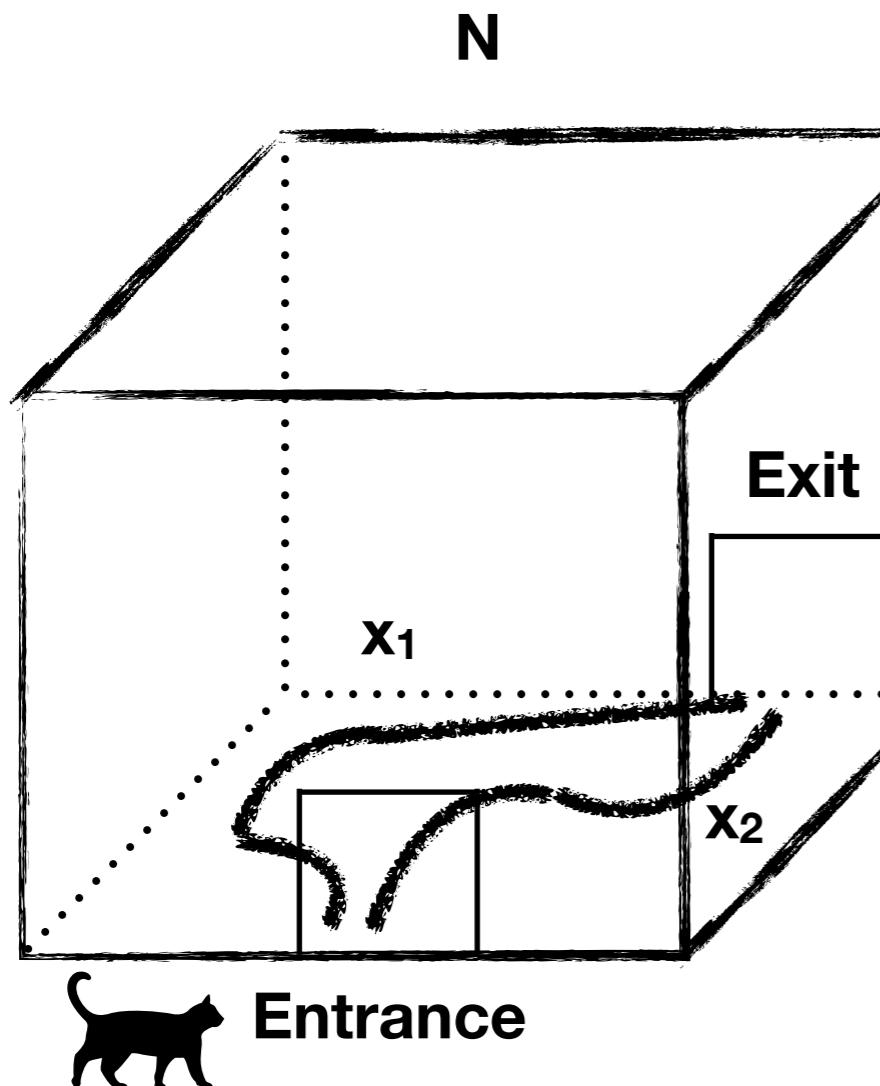
where each coefficient,  $\alpha_s$  with  $s \in \{H, H(5-2), cdm, g, BH, NS, GWS, smp, Higgs, strings, exotic\}$ , depends on the energy,  $E$ , and scale,  $r$ , applicable for each system, and it can be modelled as a step function in which it gives 1 at the Energy and scale ranges of applicability and 0 elsewhere. The energy and scale range of applicability or the whole form of these coefficients can be constrained by experiments. Note also that this section answers to the question on how the integral of all possible actions have as a limit the already studied actions. It is easy to show that applying the variational principle to Eq. 44, leads to a set of equations which describe the universe and each subsystem, with a coefficient which shows the ranges of energy and scale of applicability.

Actionic field interpretation  
Action answers to the question :



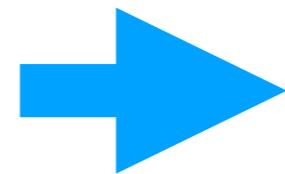
There is actually an actionic field  
everywhere & anywhere

What is the summation of all possible routes  
a cat can use to pass through each room ?



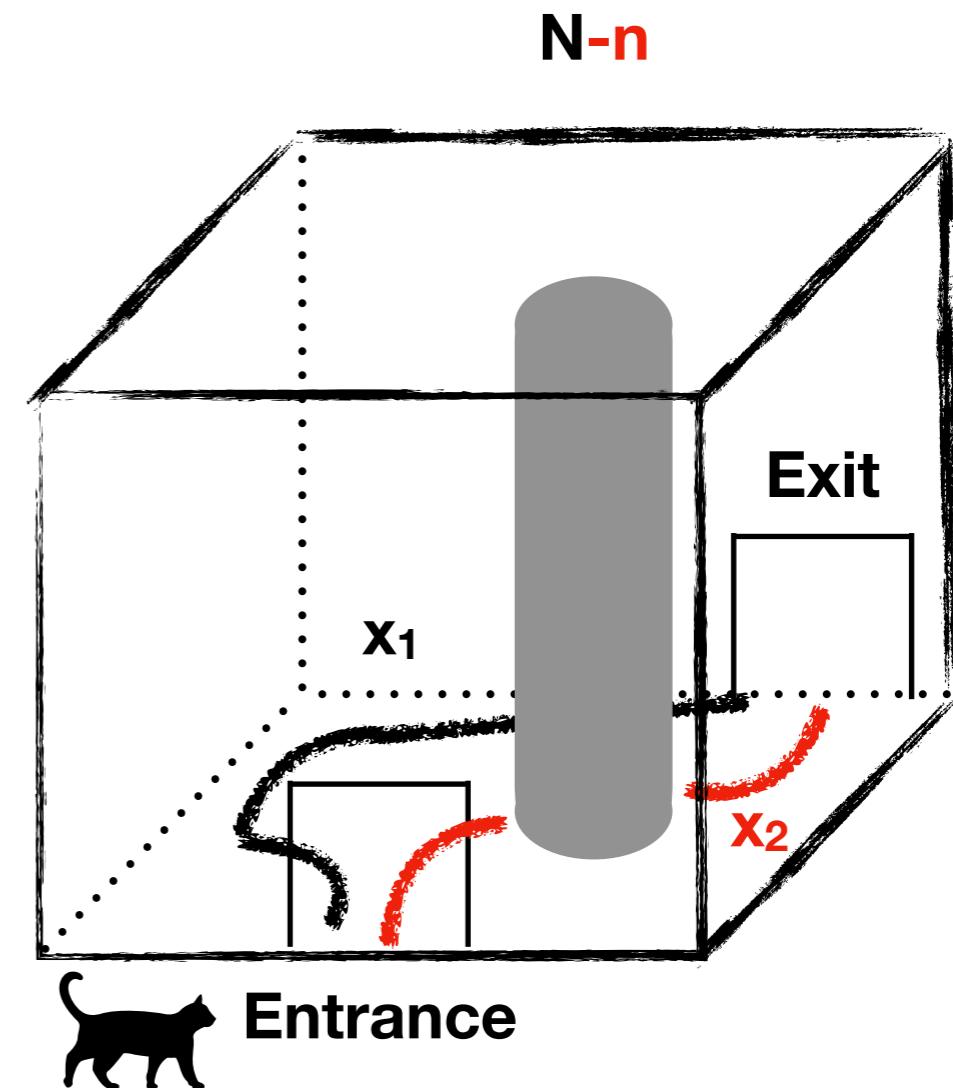
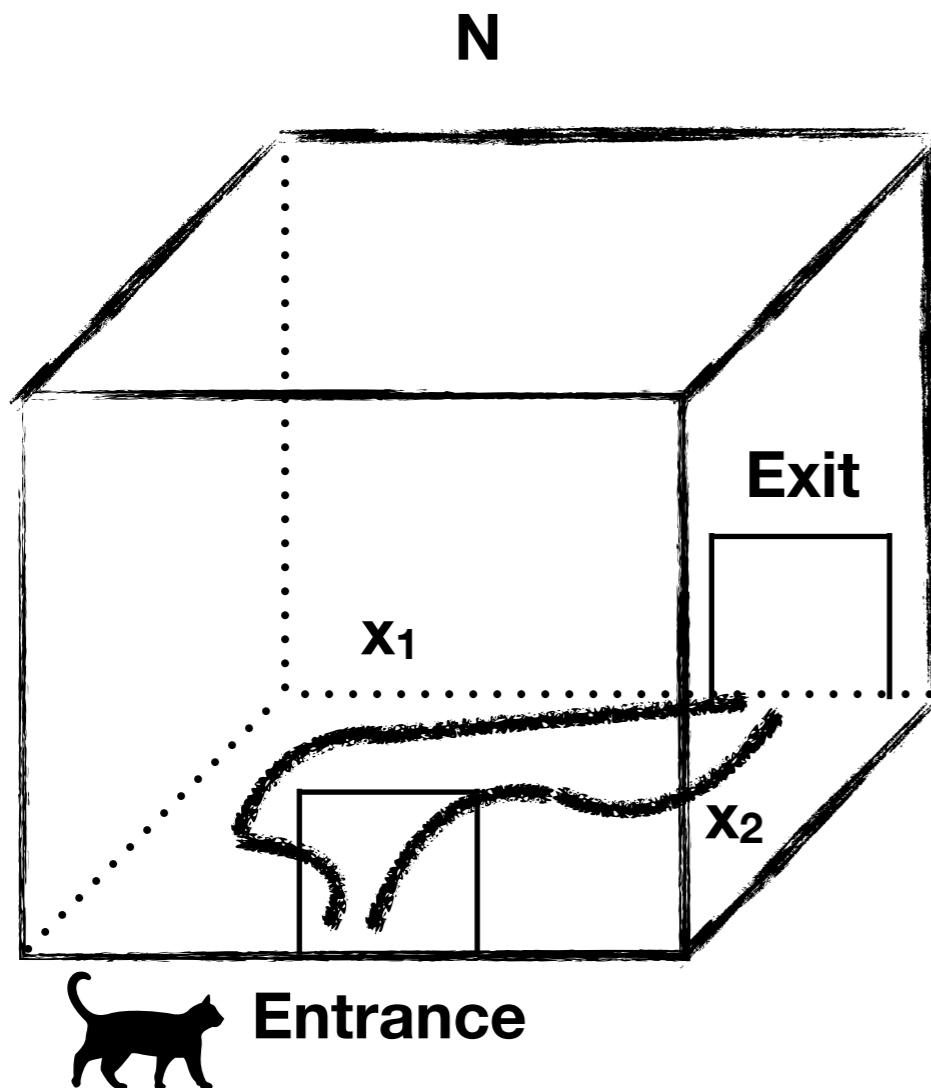
$x_1$  is possible for both rooms,  $x_2$  is not possible for the 2nd room  
space,  $x$

Actionic field interpretation  
Action answers to the question :



There is actually an actionic field  
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x<sub>1</sub> is possible for both rooms, x<sub>2</sub> is not possible for the 2nd room

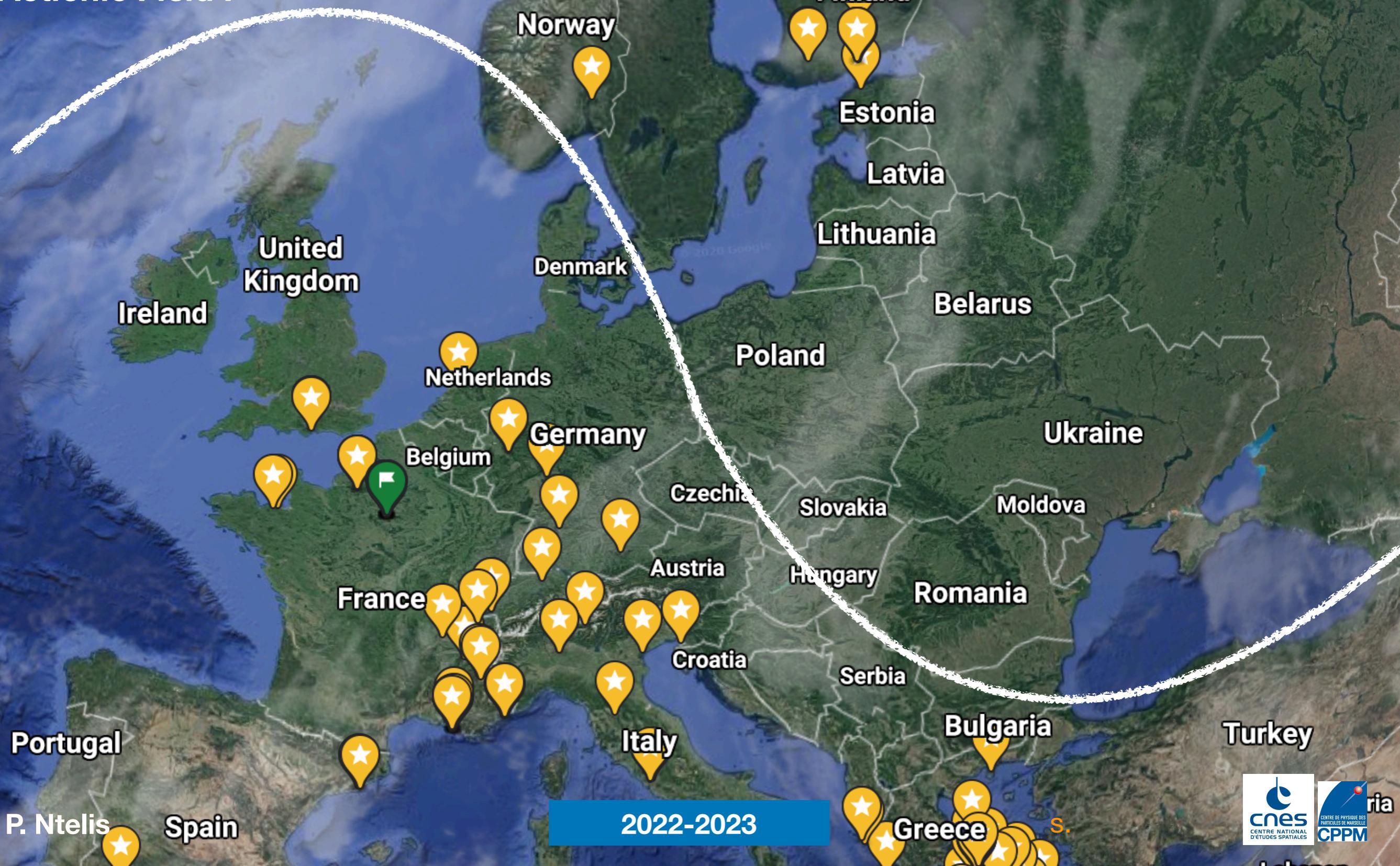
space, x

Iceland

Action answers  
to the question :

How many different ways there are  
a person passes through Europe  
from south to north ?

Actionic Field !



Iceland

Action answers  
to the question :

How many different ways there are  
a person passes through Europe  
from south to north  
during Covid-19 ?

Actionic Field !

United Kingdom

Ireland

Netherlands

Belgium

Germany

France

Portugal

P. Ntelis

Spain

2020-2021

Sweden

Norway

Denmark

Finland

Estonia

Latvia

Lithuania

Belarus

Ukraine

Poland

Czechia

Slovakia

Austria

Hungary

Croatia

Romania

Serbia

Bulgaria

Turkey

Italy

Greece

# **A $(D\tau, D_x)$ -manifold with NPCF of $Nt$ -objects**

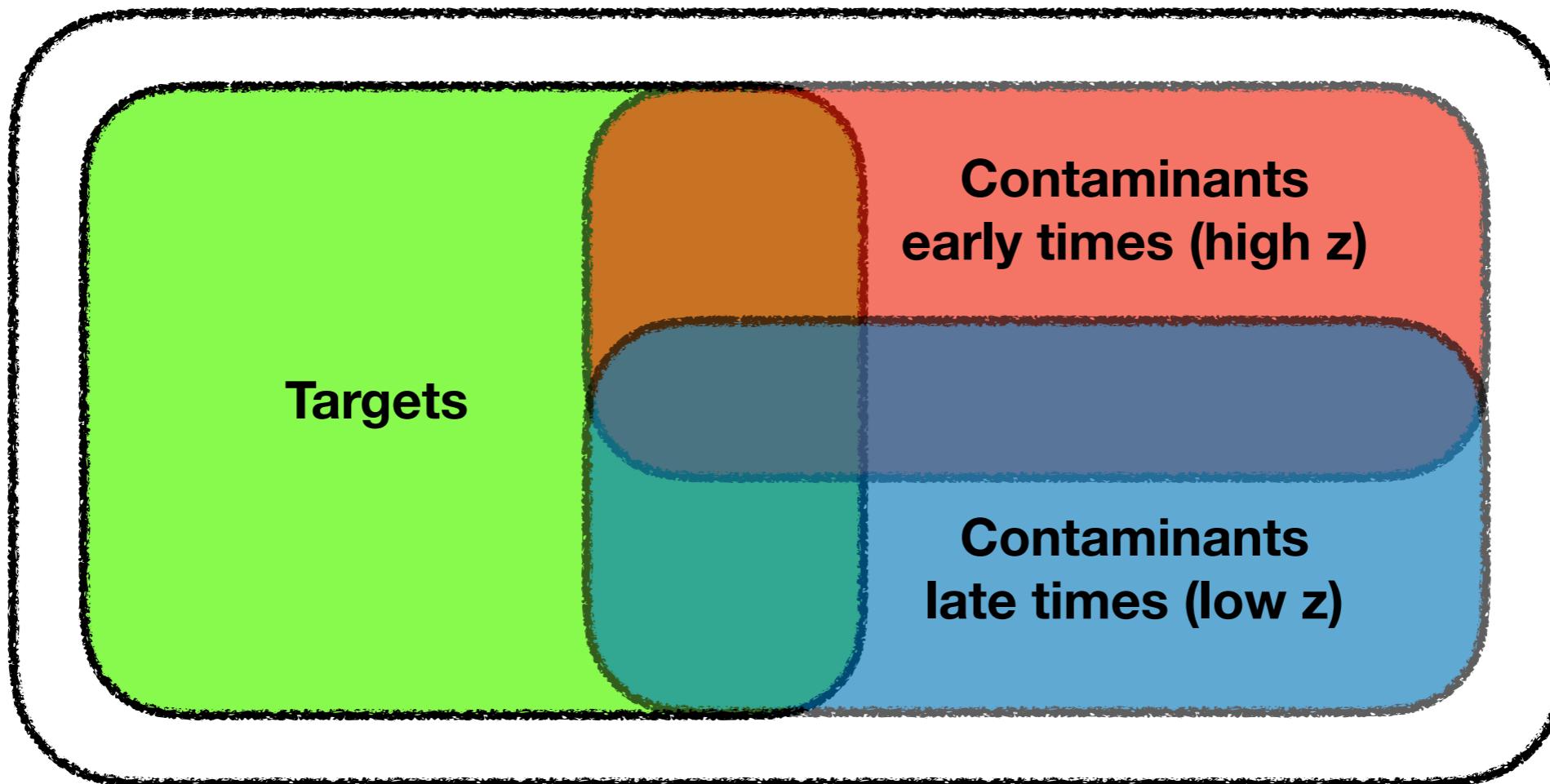
## Experimental Sample

Target

$(D_\tau, D_x)$ -dimensional-T manifold,  $\mathcal{M}_T^{(D_\tau, D_x)}$

Contaminant

$(D_\tau, D_x)$ -dimensional-C manifold,  $\mathcal{M}_C^{(D_\tau, D_x)}$



PN (2209.07472) A  $(Dt, Dx)$ -manifold with N-correlators of  $Nt$ -objects, under review

**Any contaminant sample e.g. line misidentification**

# Contaminant galaxy has a wavelength:

$$\lambda_{c \rightarrow T_L^c} = \frac{1 + z_c}{1 + z_{T_L}} \lambda_c$$

Observed at a new position:

$$\vec{Y}_{\text{distorted}} = (X_{||}/\gamma_{||}, \vec{X}_{\perp}/\gamma_{\perp})$$

under distortion coefficients:

$$\gamma_{ct,\perp} = \frac{D_A(z_t)}{D_A(z_c)}$$

$$\gamma_{ct,||} = \frac{(1+z_t)/H(z_t)}{(1+z_c)/H(z_c)}$$

## Affecting 1-point function

$$\delta_o(\vec{\tau}, \vec{x}) = \left(1 - \sum_c f_c\right) \delta_t(\vec{\tau}, \vec{x}) + \sum_c f_c \delta_c(\vec{\tau}, \vec{y})$$

Amplitude change
Shape change

Target
Contaminant

Pullen, A. R., C. M. Hirata, O. Doré, et al. 2015  
Wong, K., A. Pullen, and S. Ho 2016

## A $(D\tau, Dx)$ -manifold with NPCF of $N_t$ -objects

### Apply on large scale structure

observed matter tracer fluctuation field from  $N_t^{\text{OLSS}}$  tracers is given by

$$\delta_O(\vec{\tau}, \vec{r}) = \delta_m(\vec{\tau}_i, \vec{r}) \mathcal{FB}\mathcal{D}(\vec{\tau}, \vec{x})$$

### Functional of tensor of contaminant factor, bias, and growth of structure

$$\mathcal{FB}\mathcal{D}(\vec{\tau}, \vec{x}) = \sum_{t=1}^{N_t^{\text{OLSS}}} \left\{ \left[ 1 - \sum_{c=1}^{N_{ct}} f_{ct}(\vec{\tau}, \vec{x}) \right] b_t(\vec{\tau}, \vec{x}) D_t(\vec{\tau}, \vec{x}) + \sum_{c=1}^{N_{ct}} |\vec{\gamma}_{ct}|^{D_x}(\vec{\tau}, \vec{x}) f_{ct}(\vec{\tau}, \vec{x}) b_{ct}(\vec{\tau}, \vec{x}) D_{ct}(\vec{\tau}, \vec{x}) \right\} \quad (3.19)$$

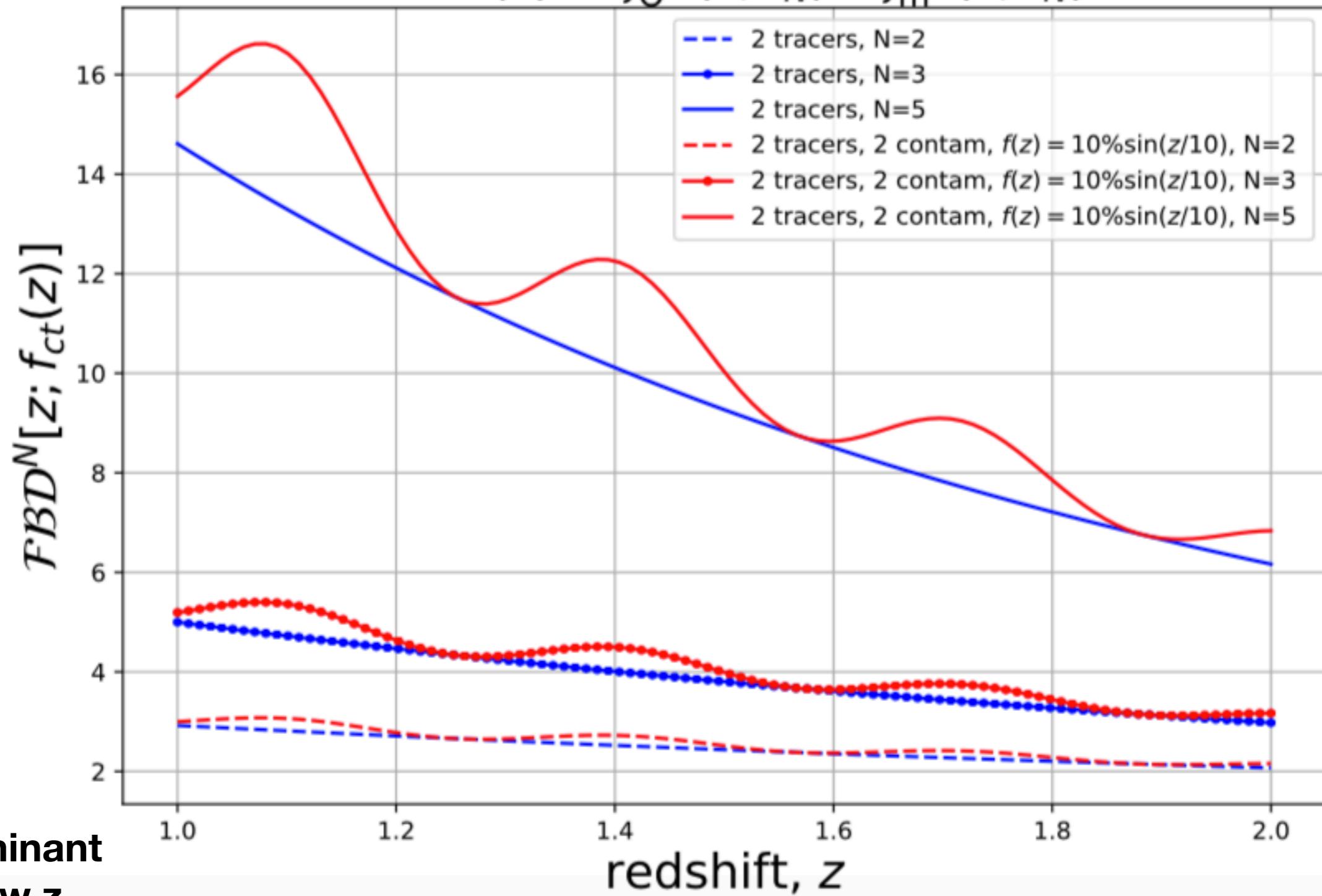
In the case which there are only scale-independent contaminant factors, biases and growths of structures for all tracers and contaminants, i.e.  $\mathcal{FB}\mathcal{D}(\vec{\tau}, \vec{x}) \rightarrow \mathcal{FB}\mathcal{D}(\vec{\tau})$ , we have that the while in fourier space we have

$$\frac{P_O^{(N)}(\vec{\tau}, \vec{k}_1, \dots, \vec{k}_{N-1})}{P_m^{(N)}(\vec{\tau}_i, \vec{k}_1, \dots, \vec{k}_{N-1})} \equiv \{\mathcal{FB}\mathcal{D}(\vec{\tau})\}^N. \quad (3.24)$$

$\vec{\tilde{k}}_N = (\vec{k}_1, \dots, \vec{k}_{N-1})$

## *A (1,3)-manifold with NPCF of Nt-objects*

$$\mathcal{FBD}^N(z) \equiv \xi_0^{(N)}(z; \vec{r}_N) / \xi_m^{(N)}(z; \vec{r}_N)$$

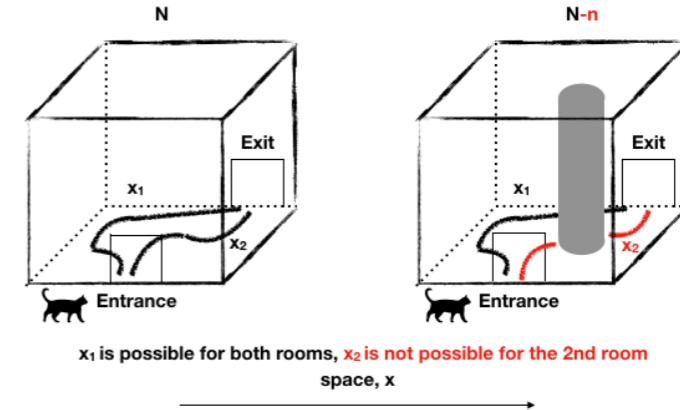


# Conclusion and outlook

Our current picture can be altered by

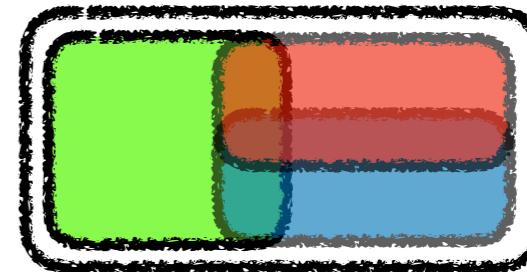
**A) Functors of Actions theories**

Applied to large scales and quantum scales  
predicting:  
– Actionic fields



**B)  $(D\tau, Dx)$ -manifold with NPCF of  $Nt$ -objects**

- extra dimensions
- contaminated samples
- Applied to
  - Large scale structure
  - Quantum scale structure



Continue ongoing work on testing these theories with several observables, in telescopes

- Dark Energy and Dark Matter
- Hubble expansion rate
- ...

***Open to your suggestions and collaborations***

[PNTELIS CV](#)  
[PNTELIS Inspires](#)  
[PNTELIS Github](#)

***Thank you for your attention!***