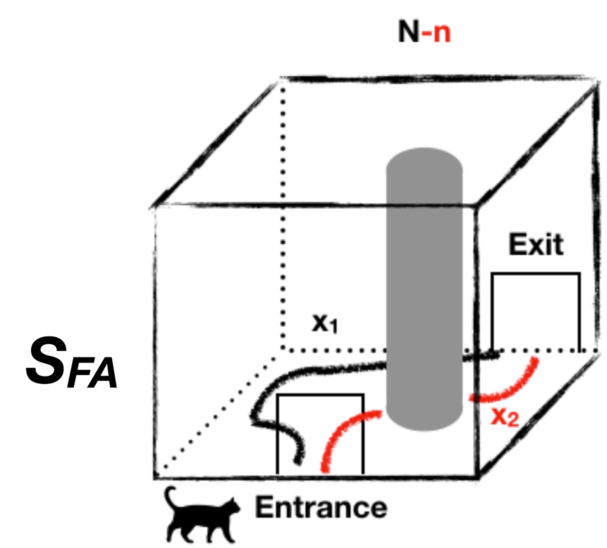
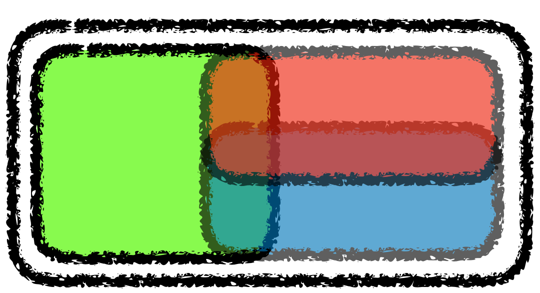
New avenues and observational constraints of functors of actions !

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
<u>Foundation of Physics Journal '23 (2010.06707)</u>





PN A (Dt,Dx)-manifold with N-correlators of Nt-objects, <u>under review (2209.07472)</u>

Outline of the talk

What is built by theoretical cosmologists ?

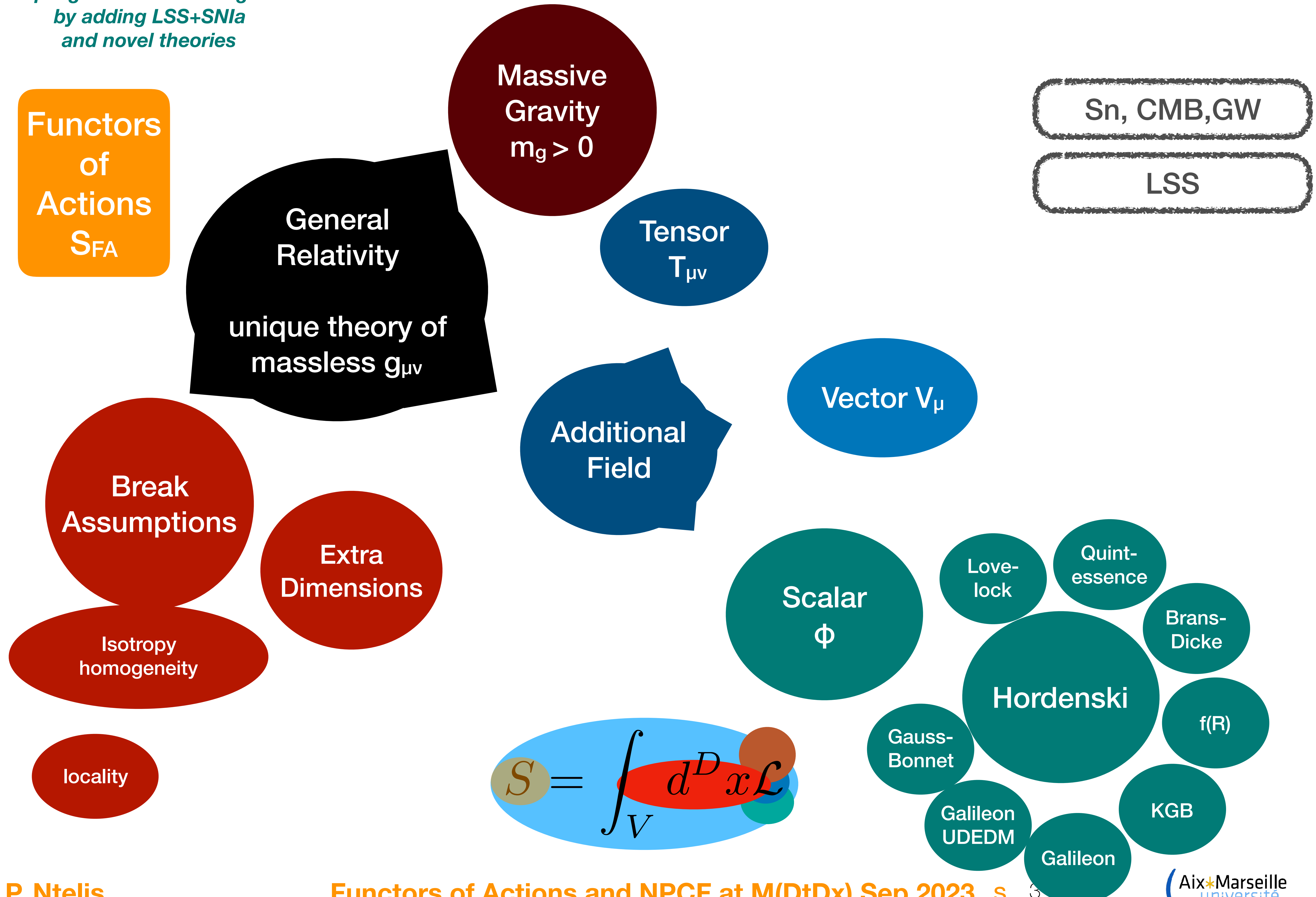
Functors of Actions (FA)
- **A guide to build models of FA**
- **Actionic field fluctuations**
- **(Simulated constraints)**

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

Diagram remodified from Ezquiaga & Zumalacárregui 18 by adding LSS+SNIa and novel theories



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.

$$\mathcal{S}_{\mathrm{FA}} \supset \int_{\Omega_{\mathrm{S}}} dS' \supset \qquad \mathcal{S}_{\mathrm{EFT}} \supset \int_{\Omega_S} dS' S' \quad \Longleftarrow \quad S = \int_V d^D x \mathcal{L}$$

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

Functors of actions

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

Example:

$$\mathcal{S}_{\rm FA} \ni \int_{\Omega_S} dS' \rightarrow \int_0^{S} dS' \overset{\text{GR limit}}{--\rightarrow} \int_0^{S_{\rm GR}} dS' = \sum_{i=1,2} S_i = S_R + S_m$$

$$= c^4 \int \sqrt{-g}\,\frac{R}{16\pi G_{\rm N}} d^4x + c^4 \int \sqrt{-g}\,\mathcal{L}_m\left(g_{\mu\nu}\right) d^4x \ ,$$

$$S_{\rm GR} \equiv c^4 \int \sqrt{-g}\left[\frac{R}{16\pi G_{\rm N}} + \mathcal{L}_m\left(g_{\mu\nu}\right)\right] d^4x \ .$$

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Functors of actions

8. *Strings limits*

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

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

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 σ, while the timelike coordinate is denoted with τ.

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Functors of actions

Prediction of Modification of Einstein Field Equations

$$\boxed{\mathcal{S}^{\text{Simplified,2,GR,2}}_{\text{EFT}} = \beta^{(S_R)} S_R + \alpha^{(S_m)} + S_m + S_3'}$$

Prediction of Actionic fields (similar to energy fields)

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

$$0 = \int d^4x \sqrt{-g} \delta g^{\mu\nu} \left(\beta^{(S_R)} \frac{c^4}{16\pi G_{\mathrm{N}}} \left(R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} + \Lambda g_{\mu\nu} \right) - T_{\mu\nu}/2 \right) \boxed{+ \delta S_3'}$$

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

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Functors of actions

Constraints and Prediction of Modification of EFE

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

Prediction of Actionic fields,
by choosing a special Lagrangian fluctuation

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

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

Equation of state

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

for **w ~ -0.9**
=>
δL_3 ~ 0.1

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Functors of actions

Constraints and Prediction of Modification of EFE

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

Stationary Action Principle

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

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

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

Modification of G_{eff}

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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, Ω_S^{KE}, then the full action which describes the universe as a whole, $S_{\rm FA,U}$, which will be constucted via a space of actions of the whole universe, $\Omega_S^U = \{-\alpha_{\rm exotic}S_{\rm exotic}, ..., \alpha_H S_H\}$, 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, $S_{\rm exotic}$. These will be the limit of the action describing the whole universe which will include the reduced Hordenski action as defined earlied, $S_{H(2-5)}$, 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, $S_{\rm m,Higgs}$, the strings action, $S_{\rm strings}$,as well as some exotic system that we have not discovered yet. Therefore we can write,

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

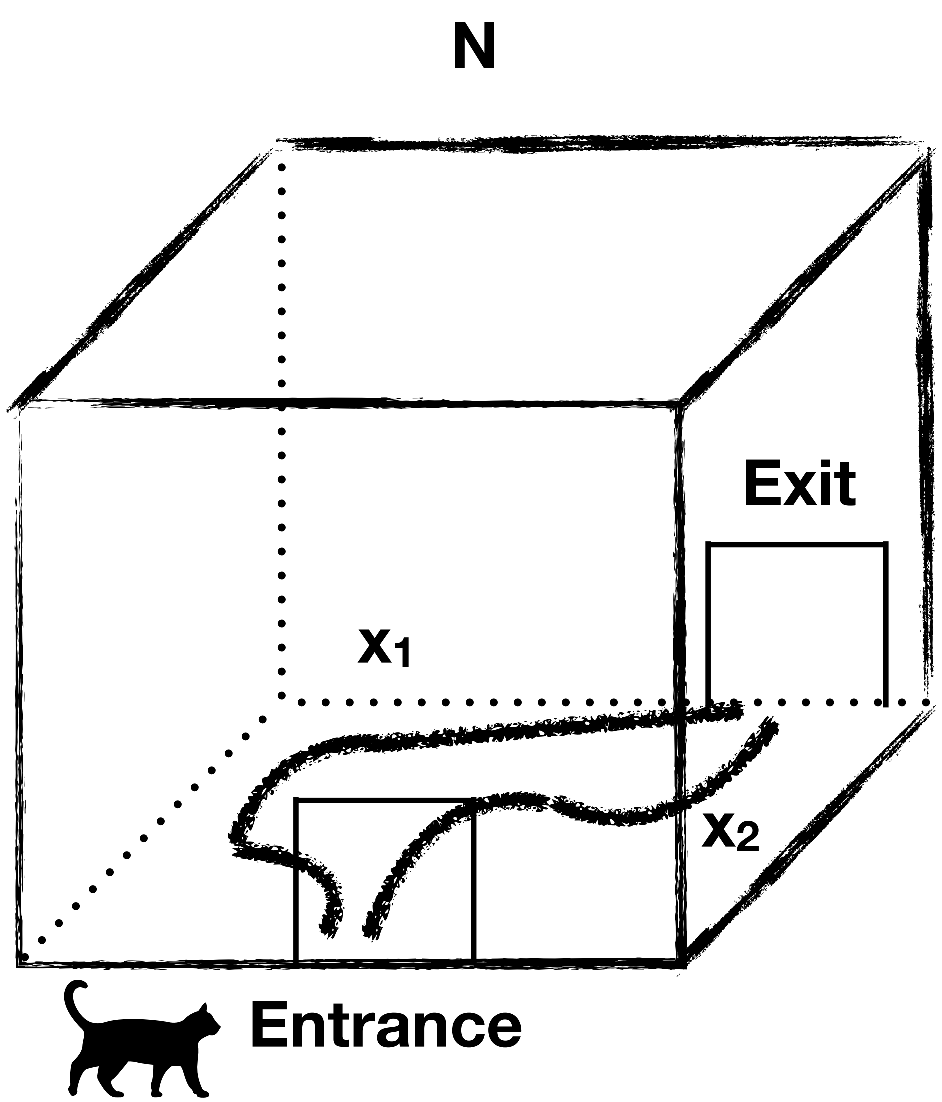
$$\begin{aligned} S_{\rm FA,U} = {}& \alpha_{H(2-5)}S_{H(2-5)} + \sum_{cdm=1}^{\infty} \alpha_{cdm}S_{cdm} + \sum_{g=1}^{\infty}\alpha_g S_g \\ & + \sum_{BH=1}^{\infty}\alpha_{BH}S_{BH} + \sum_{NS=1}^{\infty}\alpha_{NS}S_{NS} + \sum_{GWS=1}^{\infty}\alpha_{GWS}S_{GWS} \\ & + \alpha_{smp}S_{smp} + \alpha_{\rm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

where each coefficient, α_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

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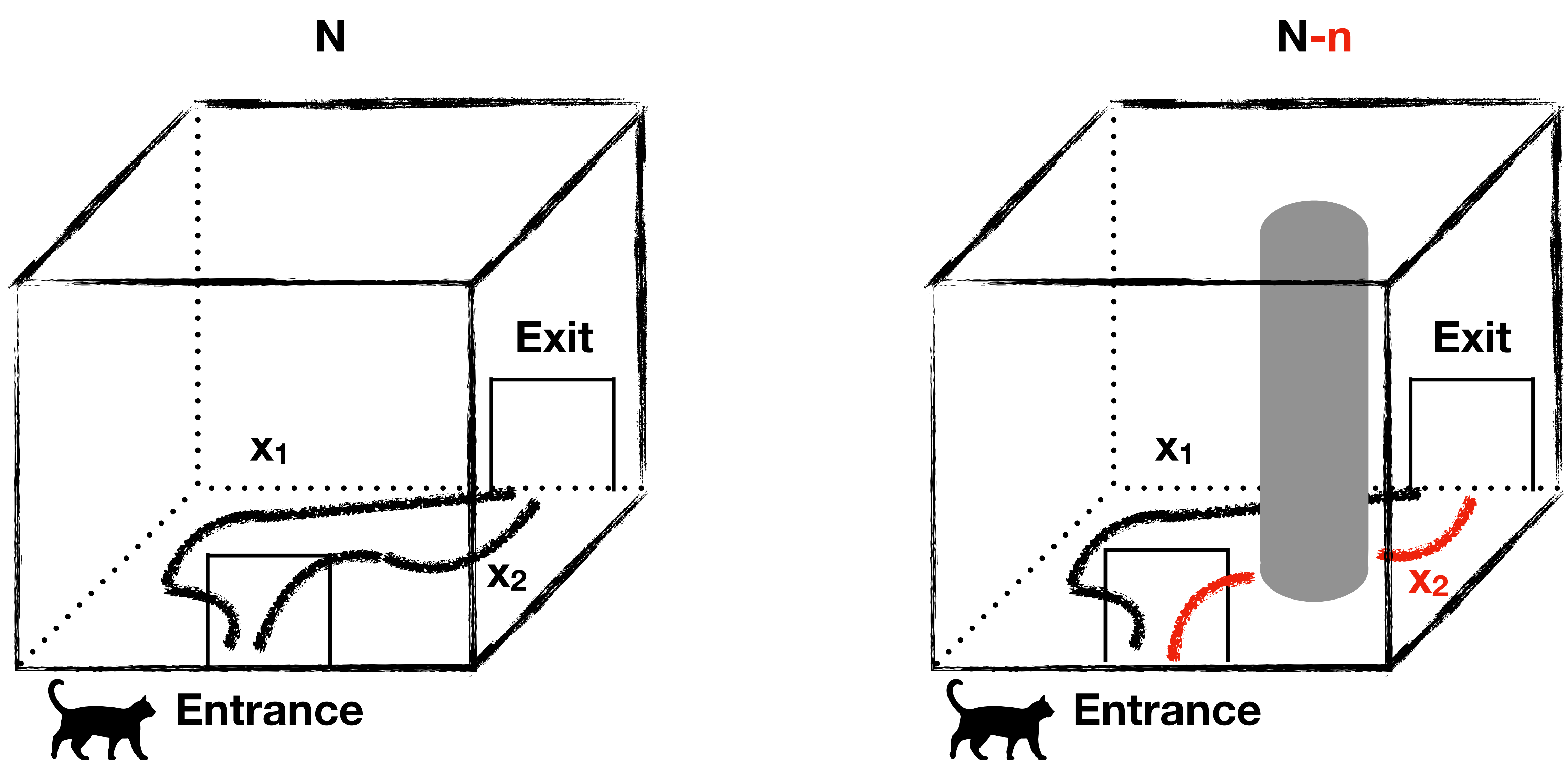

x_1 is possible for both rooms, x_2 is not possible for the 2nd room

space, x

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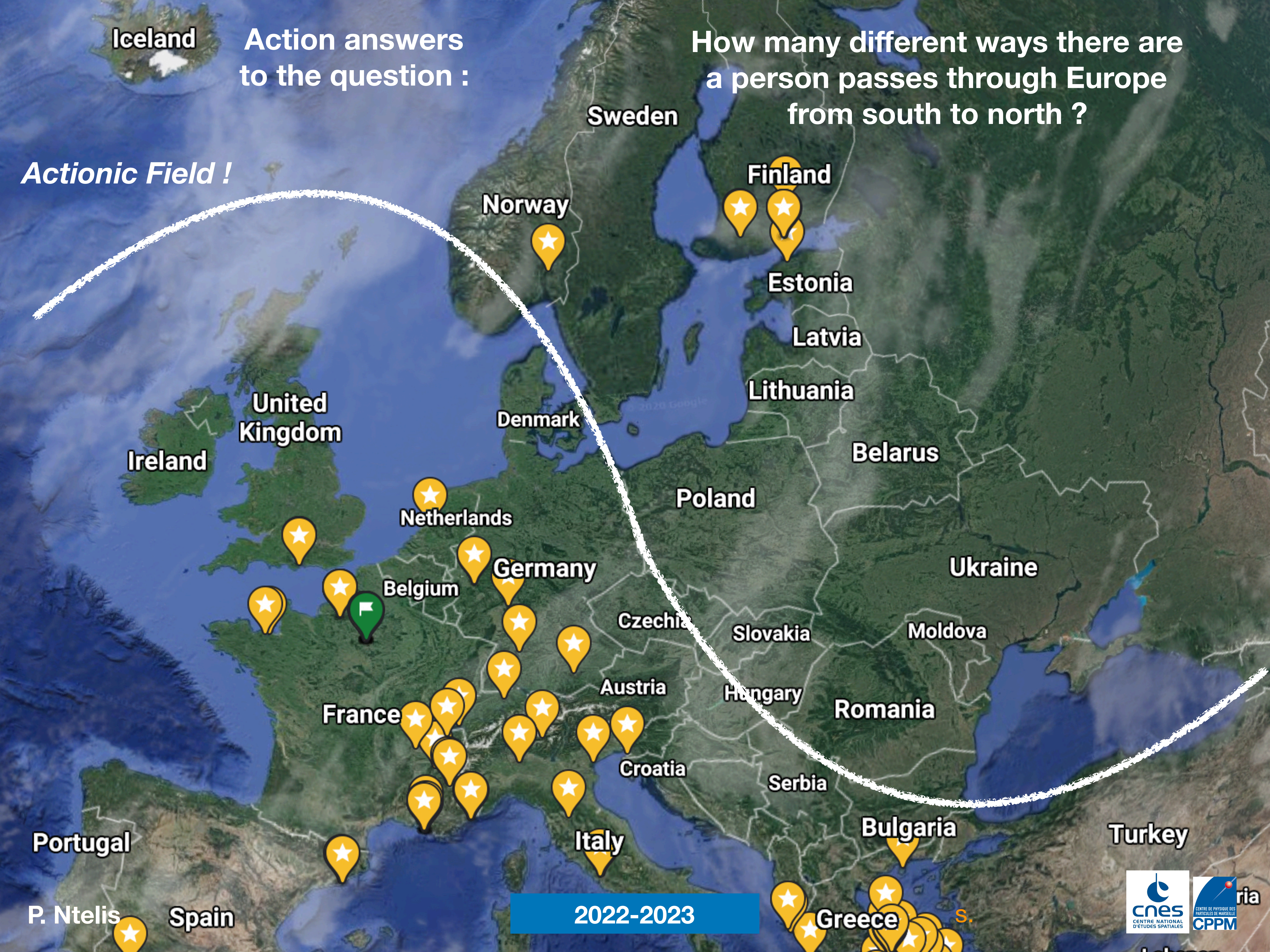
Action answers
to the question :
How many different ways there are
a person passes through Europe
from south to north ?
Actionic Field !
Iceland
Sweden
Norway
Finland
Estonia
Latvia
Lithuania
Denmark
United Kingdom
Ireland
Belarus
Poland
Netherlands
Germany
Belgium
Ukraine
Czechia
Slovakia
Moldova
Austria
Hungary
France
Romania
Croatia
Serbia
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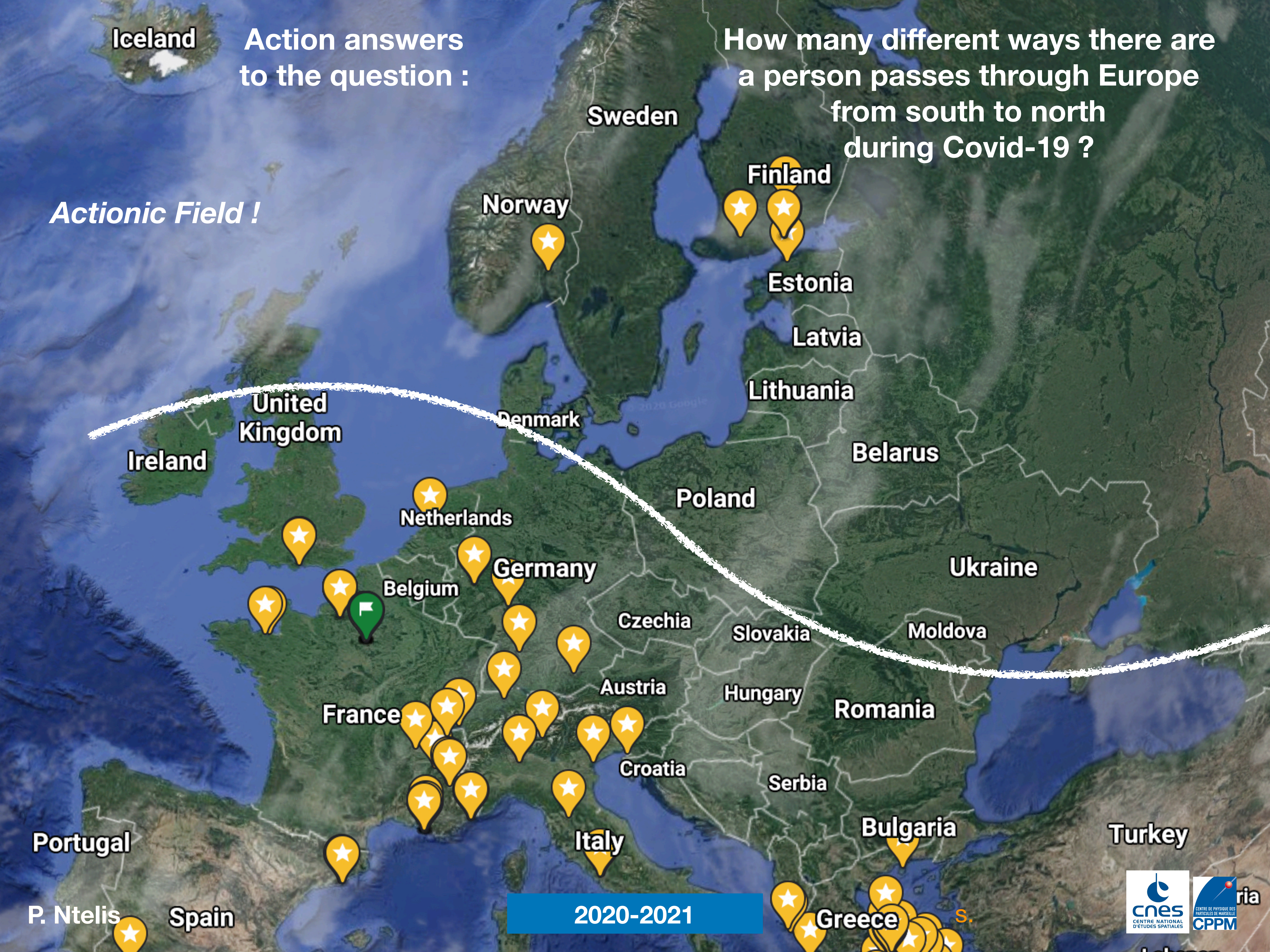
Action answers
to the question :
How many different ways there are
a person passes through Europe
from south to north
during Covid-19 ?
Actionic Field !
Iceland
Sweden
Finland
Norway
Estonia
Latvia
Lithuania
United
Kingdom
Denmark
Ireland
Belarus
Poland
Netherlands
Germany
Ukraine
Belgium
Czechia
Slovakia
Moldova
Austria
Hungary
Romania
France
Croatia
Serbia
Bulgaria
Italy
Portugal
Turkey
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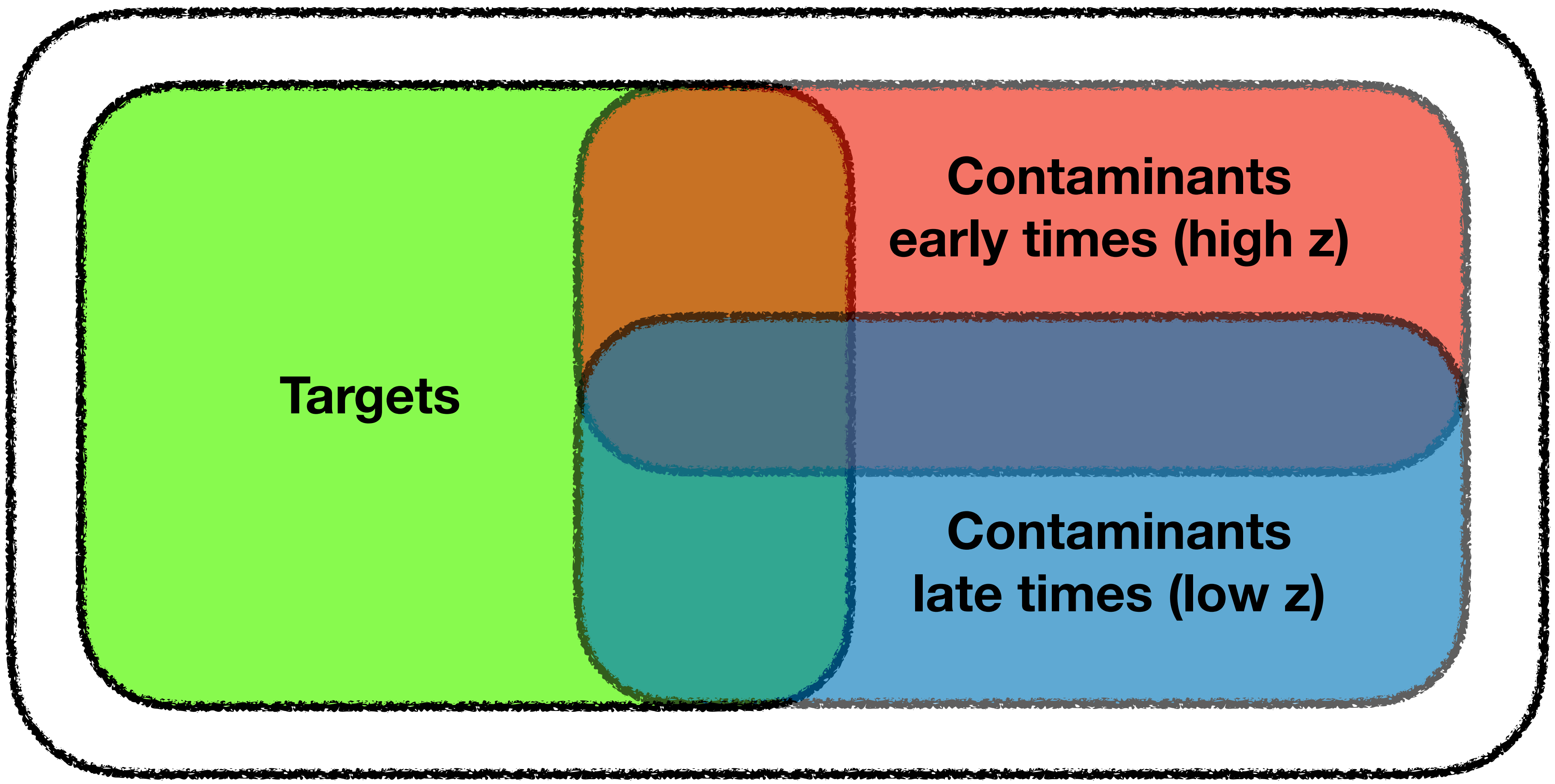
A (Dτ,Dx)-manifold with NPCF of Nt-objects

<u>Experimental Sample</u>

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

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



<u>PN (2209.07472) A (Dt,Dx)-manifold with N-correlators of Nt-objects, under review</u>

Any contaminant sample e.g. line misidentification

Contaminant galaxy has a wavelength: $$\lambda_{c \to T_L^c} = \frac{1+z_c}{1+z_{T_L}} \lambda_c$$

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

Amplitude change **Shape change**

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

|– – Target – –| **|– – Contaminant – –|**

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

Apply on large scale structure

observed matter tracer fluctuation field from $N_{\mathrm{t}}^{\mathrm{OLSS}}$ tracers is given by

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

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

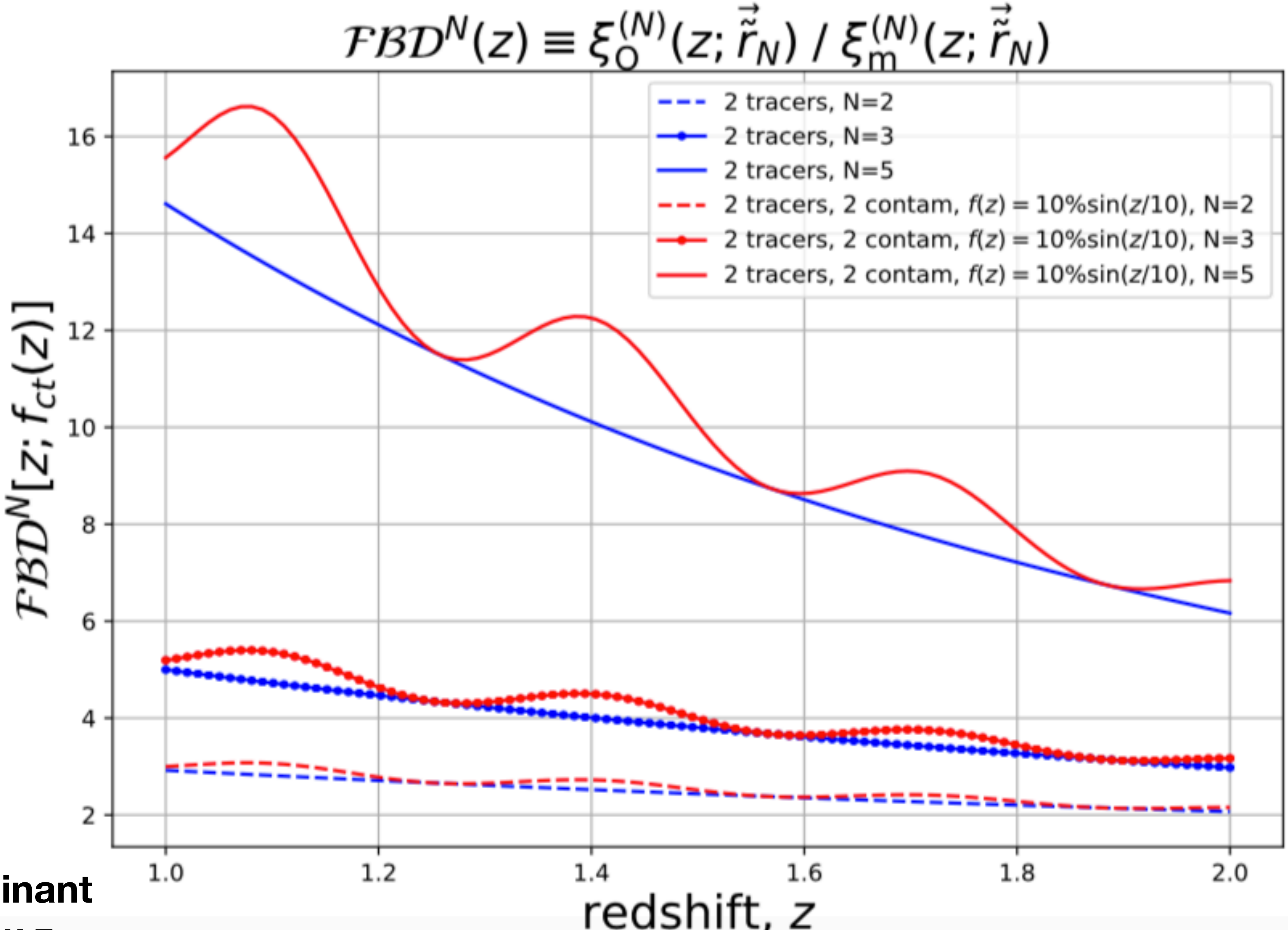
$$\mathcal{FBD}(\vec{\tau},\vec{x}) = \sum_{t=1}^{N_{\mathrm{t}}^{\mathrm{OLSS}}} \left\{ \left[1 - \sum_{c=1}^{N_{ct}} f_{ct}(\vec{\tau},\vec{x})\right] b_t(\vec{\tau},\vec{x}) D_t(\vec{\tau},\vec{x}) + \sum_{c=1}^{N_{ct}} |\vec{\gamma}_{ct}|^{D_x}(\vec{\tau},\vec{x}) f_{ct}(\vec{\tau},\vec{x}) b_{ct}(\vec{\tau},\vec{x})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

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

$$\frac{P_{\mathrm{O}}^{(N)}(\vec{\tau},\vec{k}_1,\ldots,\vec{k}_{N-1})}{P_{\mathrm{m}}^{(N)}(\vec{\tau}_i,\vec{k}_1,\ldots,\vec{k}_{N-1})} \equiv \{\mathcal{FBD}(\vec{\tau})\}^N \ . \tag{3.24}$$

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

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



contaminant from low z different behaviour [See document]

targeted redshift range of interest, $1 \leq z \leq 2$

contaminant redshift range of interest, $z_c \in [2.0, 2.5]$

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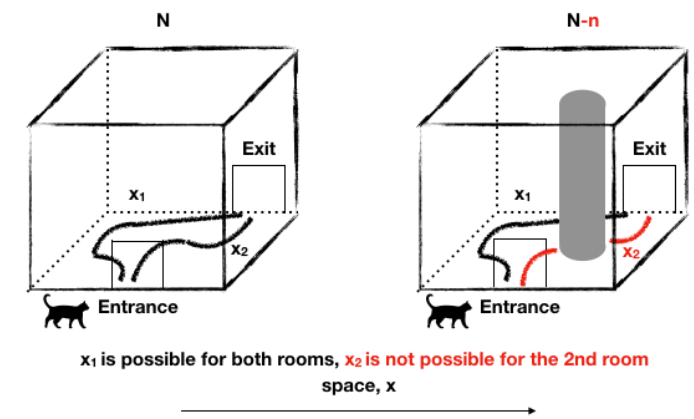
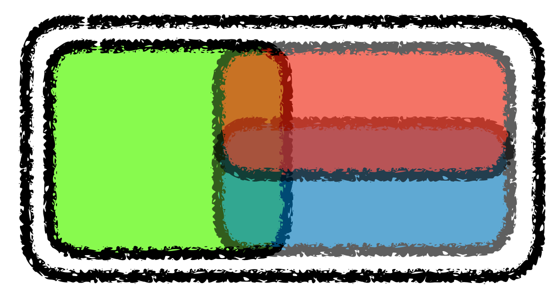
Conclusion and outlook

Our current picture can be altered by



A) Functors of Actions theories
Applied to large scales and quantum scales predicting:
- **Actionic fields**



B) (Dτ,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

Thank you for your attention!