Title: Parametrizing general linear cosmological perturbations

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Abstract: <p>We have great certainty on how gravity works around our solar system: General Relativity (GR) has been found to be very accurate at these small scales. On large scales though, we still have a considerable lack of understanding about the evolution of the universe, and its constituents. While the LCDM model is in good agreement with cosmological data, this might change in the future. For this reason, we need to test GR on these scales.

There are a number of proposals on how to characterize deviations from GR on larges scales, by parametrizing different cosmological evolutions of the universe - the PPF, EFT and EA approaches. The objective is to use experimental data to constrain these parameters, and thus identify the most accurate cosmological model. In this talk I will show an alternative, systematic and general, parametrization method, in which we construct the most general quadratic action for linear cosmological perturbations, given some field content and gauge symmetries. I will show the example of linearly diffeomorphism-invariant scalar-tensor theories, in which case the parametrization encompasses well-known theories such as Horndeski and Beyond Horndeski. The method can straightforwardly be applied to any gravity theory with any fields and gauge symmetries.</p>

I Introduction

* GR at small scales

  i) GR fits data

  ii) Model-independent test.

  ↳ PPN

* GR at large scales

i) GR fits data

↳ Unknown components

ii) Model-independent test

theory

i) Background: Hom & isotropic

* $\bar{g}_{\mu\nu}$: $d\bar{s}^2 = -dt^2 + a^2(t)\,d\vec{x}^2$
* Matter + extra fields

ii) Perturbations

* $g_{\mu\nu} = \bar{g}_{\mu\nu}(t) + \delta g_{\mu\nu}(\vec{x}, t)$
* Matter + extra fields

Example: GR action

$$S = \int d^4x \sqrt{-g}\,(R + \mathcal{L}_m)$$

$$\Big\downarrow \text{Taylor}$$

$$S = \underbrace{S^{(0)}}_{} + \underbrace{S^{(1)}}_{\text{0th eq}} + \underbrace{\boxed{S^{(2)}}}_{\text{1st eq}}$$

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III.1 EFT of DE (Gubitosi et al 2013)

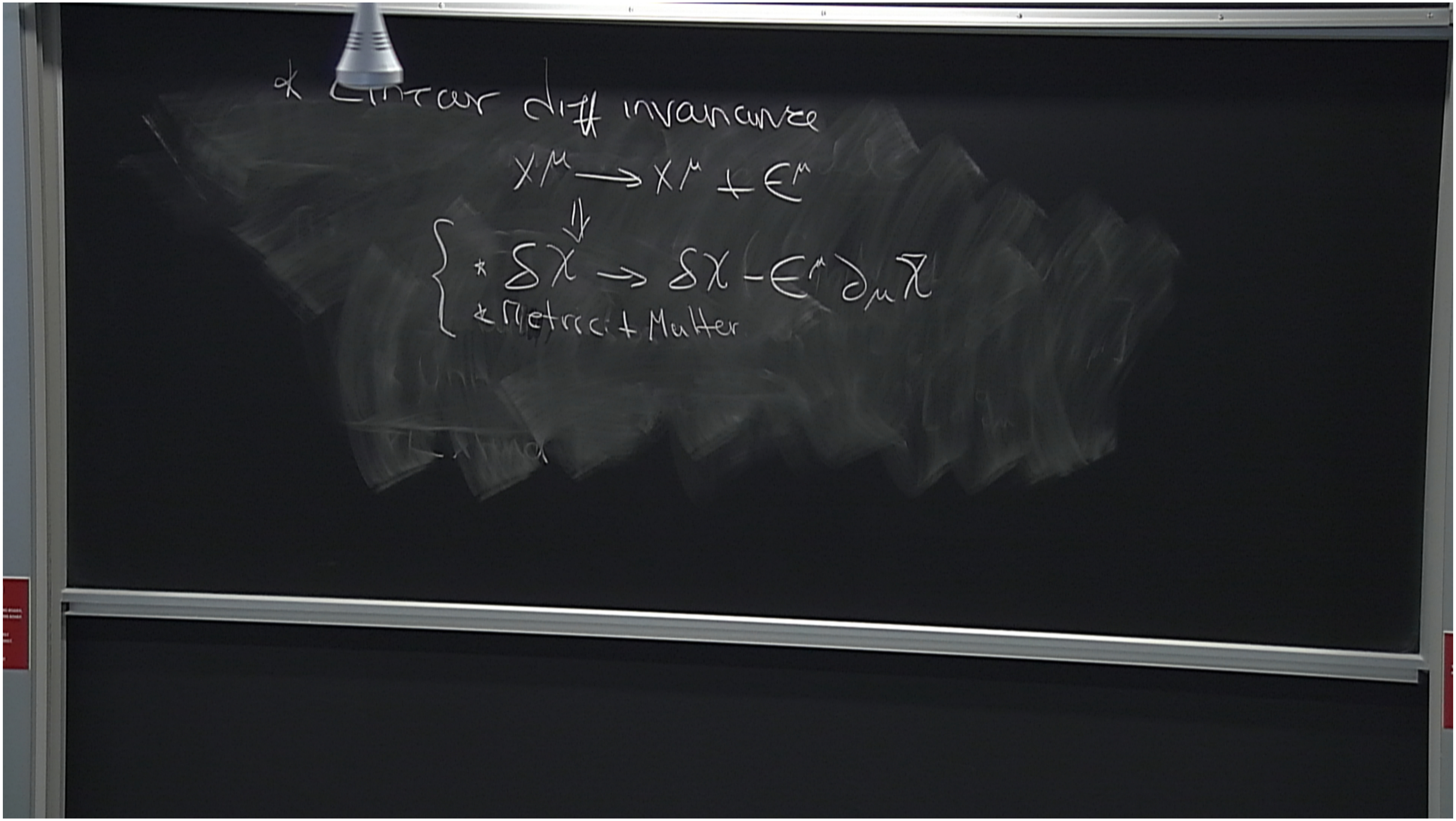
* Scalar-tensor theories $\quad S_G^{(2)}[\delta\chi, \delta g_{\mu\nu}]$
* Unitary gauge $\xrightarrow{\delta\chi=0} S_G^{(2)}[\delta g_{\mu\nu}]$
* Extend ?

III.2 Alternative Parametrization: Noether Id

3 Steps

Step: Field content; gauge symmetry;

Ansatz = back + pert


* Linear diff invariance
Xμ → Xμ + ϵμ
* δχ → δχ − ϵμ ∂μ χ̄
* Metric + Matter

Step 2. Construct S_6 + Max Derivatives.

i) Write down all quadratic interaction +
free parameters.

ii) Free params expressed in terms of underlying theory
(Gleyzes et al 2013)

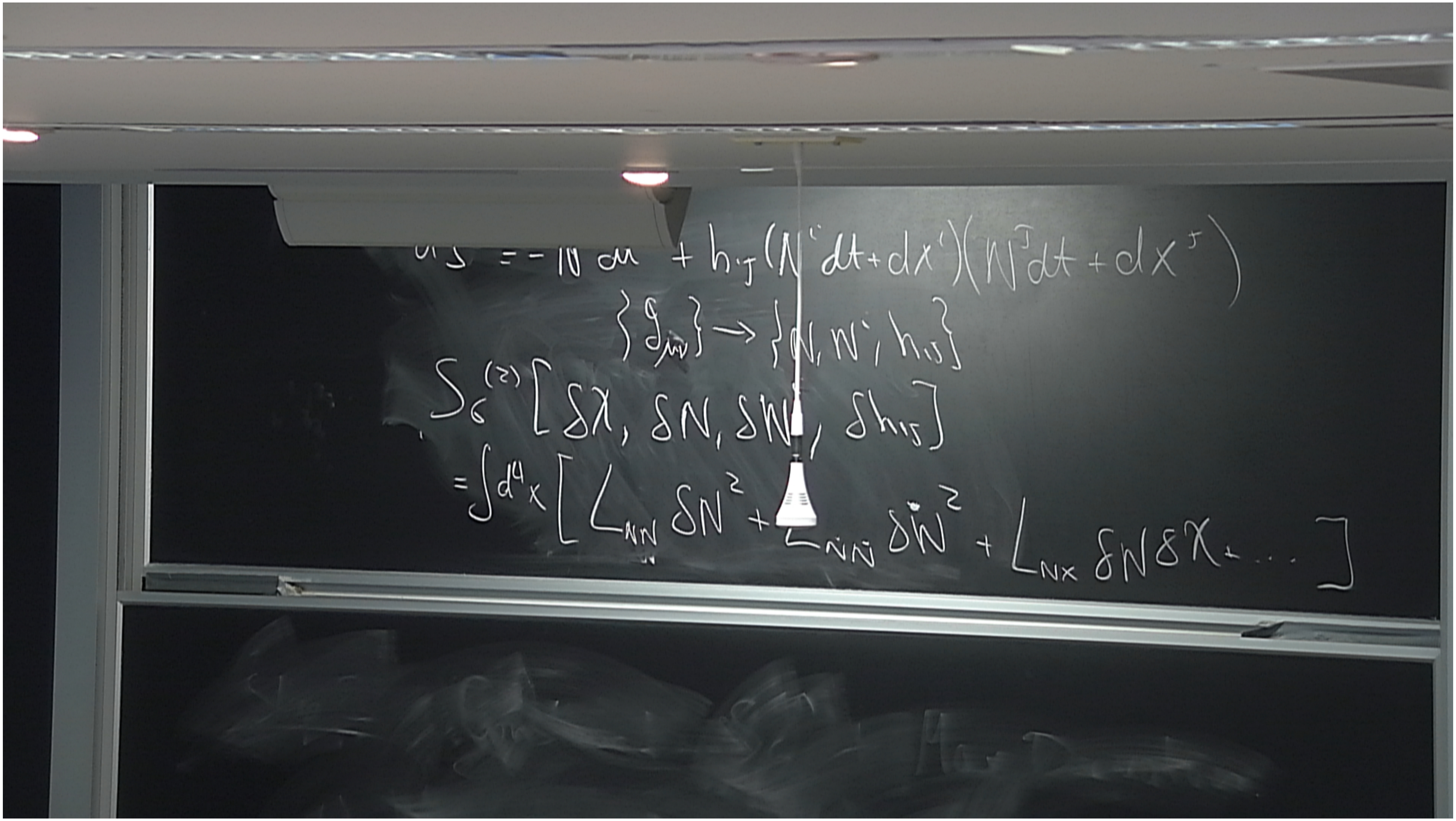
Example: ST theory + max 2 derivatives.

$$S_c^{(2)}[\delta\chi, \delta g_{\mu\nu}]$$

ADM

$$ds^2 = -N^2 dt^2 + h_{ij}(N^i dt + dx^i)(N^j dt + dx^j)$$

$$\{g_{\mu\nu}\} \to \{N, N^i, h_{ij}\}$$


$= -N^2 dt^2 + h_{ij}(N^i dt + dx^i)(N^j dt + dx^j)$
$\{g_{\mu\nu}\} \to \{N, N^i, h_{ij}\}$
$S_G^{(2)}[\delta\chi, \delta N, \delta N^i, \delta h_{ij}]$
$= \int d^4x \, [L_{NN}\,\delta N^2 + L_{\dot N \dot N}\,\delta \dot N^2 + L_{N\chi}\,\delta N\,\delta\chi + \dots]$

~50 free params

Step 3 Gauge invariance : Noether id

$$S_T^{(2)} = S_G^{(2)} + S_M^{(2)}$$

$$\delta_g S_T^{(2)} = 0$$

$$S_G^{(2)}[\delta\chi, \delta N, \delta N^i, \delta h_{ij}]$$

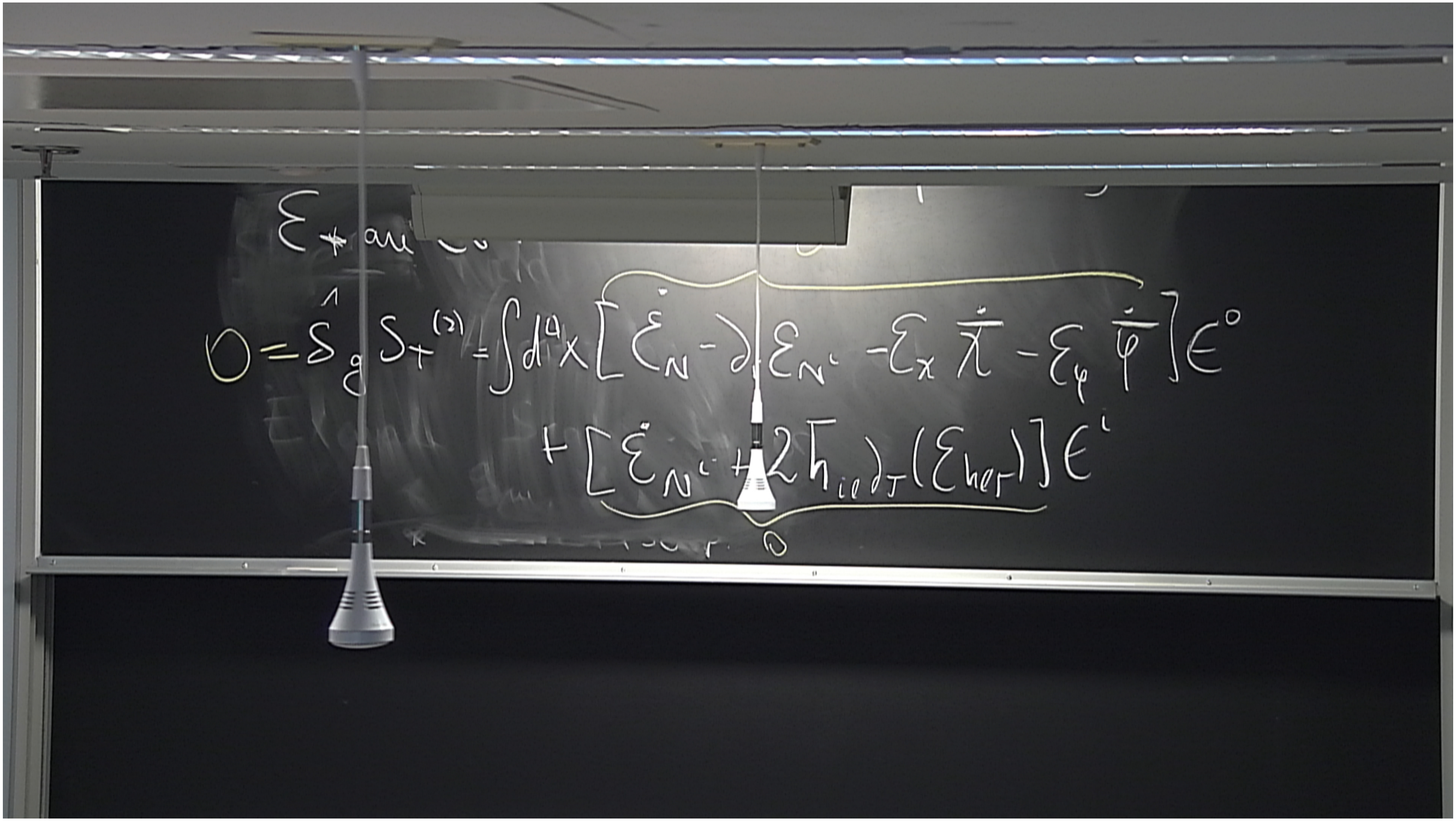
~ 50 free params

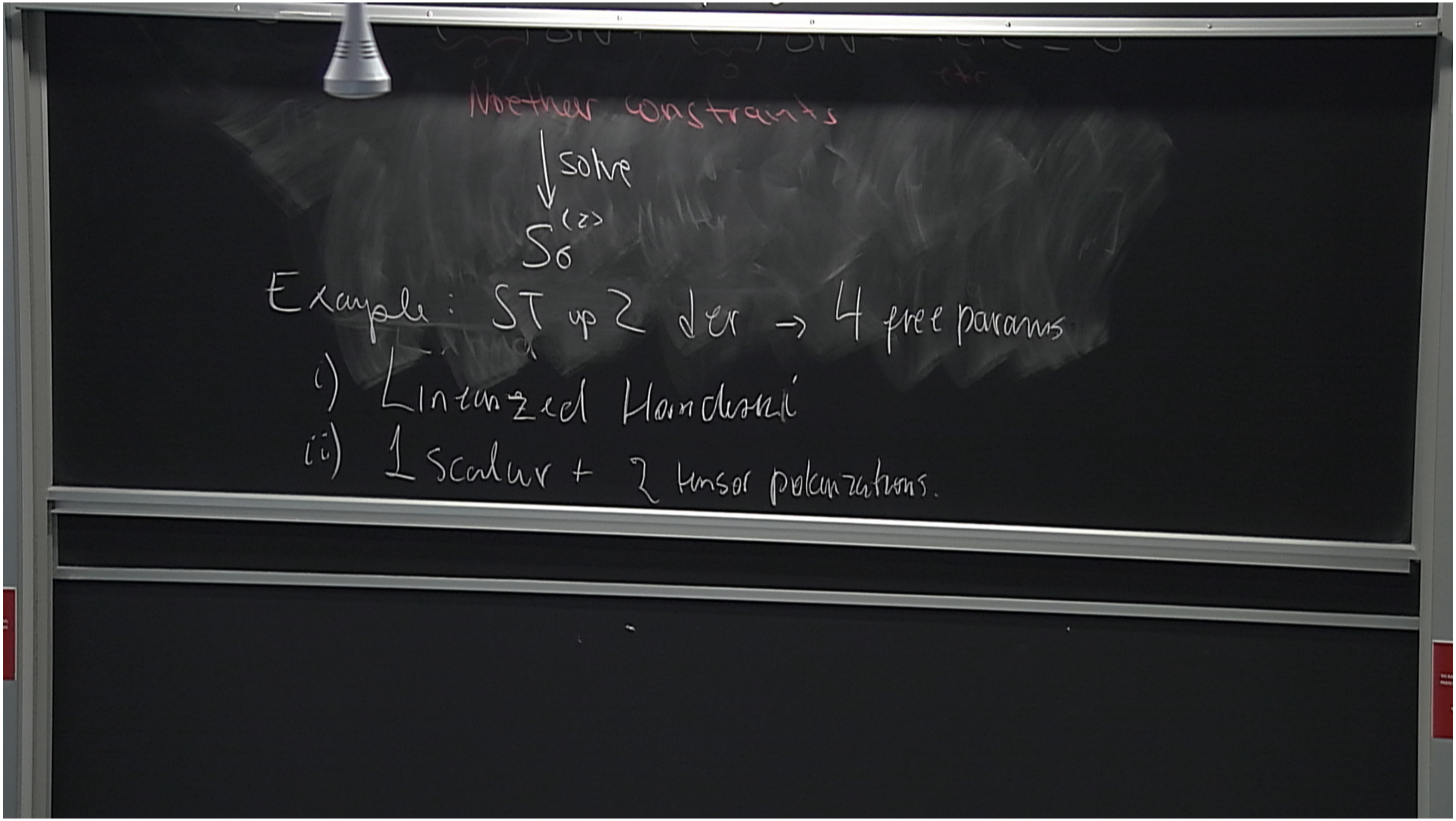
$\delta N^i, \delta N^i$ $\delta N \delta N$

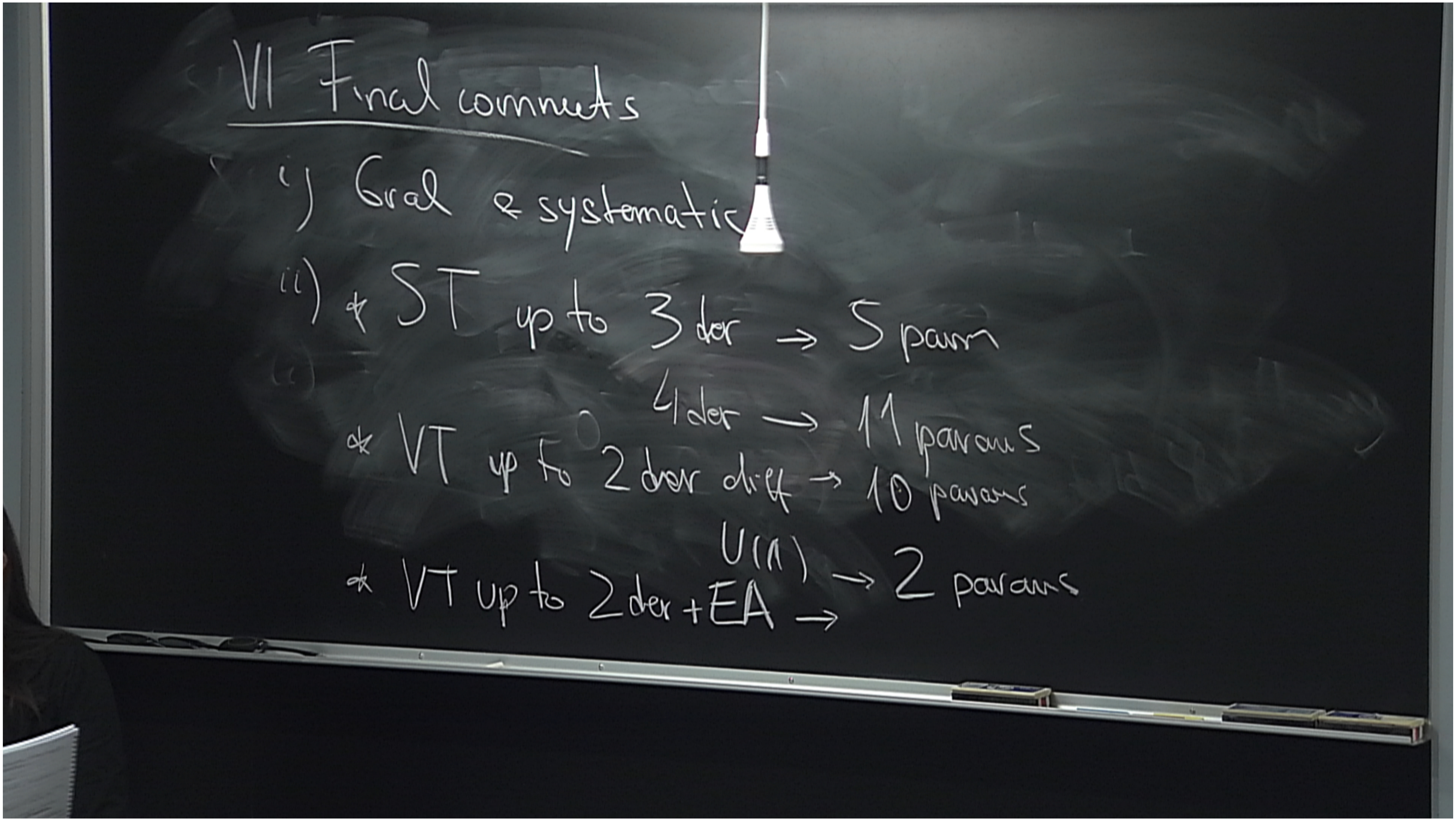
Step 3 Gauge invariance : Noether id.

$$S_T^{(2)} = S_G^{(2)} + \underbrace{S_m^{(2)}}_{\text{Quintessence field } \varphi}$$

$$\underbrace{\delta_g S_T^{(2)}}=0$$


$0 = \hat{\delta}_g S_T^{(2)} = \int d^4x \left[\dot{\mathcal{E}}_N - \partial_i \mathcal{E}_{N^i} - \mathcal{E}_\chi \dot{\chi} - \mathcal{E}_\varphi \dot{\varphi} \right] \epsilon^0$
$+ \left[\dot{\mathcal{E}}_{N^i} + 2 \bar{h}_{il} \partial_J (\mathcal{E}_{h_{lJ}}) \right] \epsilon^i$


Noether constraints
solve
$S_0^{(2)}$
Example: ST up 2 der → 4 free params
i) Linearized Horndeski
ii) 1 scalar + 2 tensor polarizations.


VI Final comments
i) Gral & systematic
ii) * ST up to 3 der → 5 param
4 der → 11 params
* VT up to 2 der diff → 10 params
U(1) → 2 params
* VT up to 2 der + EA →

VI Final comments

i) Gral & systematic

ii) * ST up to 3 der → 5 param

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