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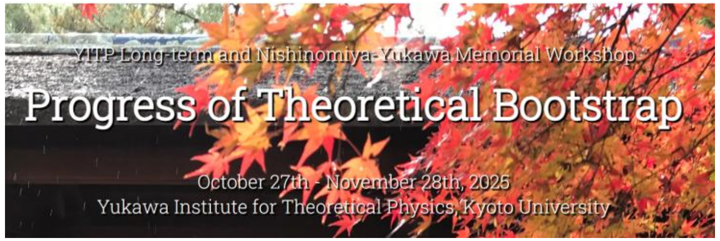


17/11/2025

Unitary renormalisation and the breaking of cosmological reality

Xi Tong
DAMTP

With: Diksha Jain, Enrico Pajer, David Stefanyszyn, Yuhang Zhu, Tao Liu, Yi Wang and Zhong-Zhi Xianyu

Based on:
- 2509.02696
- 2309.07769 (JHEP)
- 1909.01819 (JHEP)

Outline

1. Primordial cosmology and the cosmological wavefunction

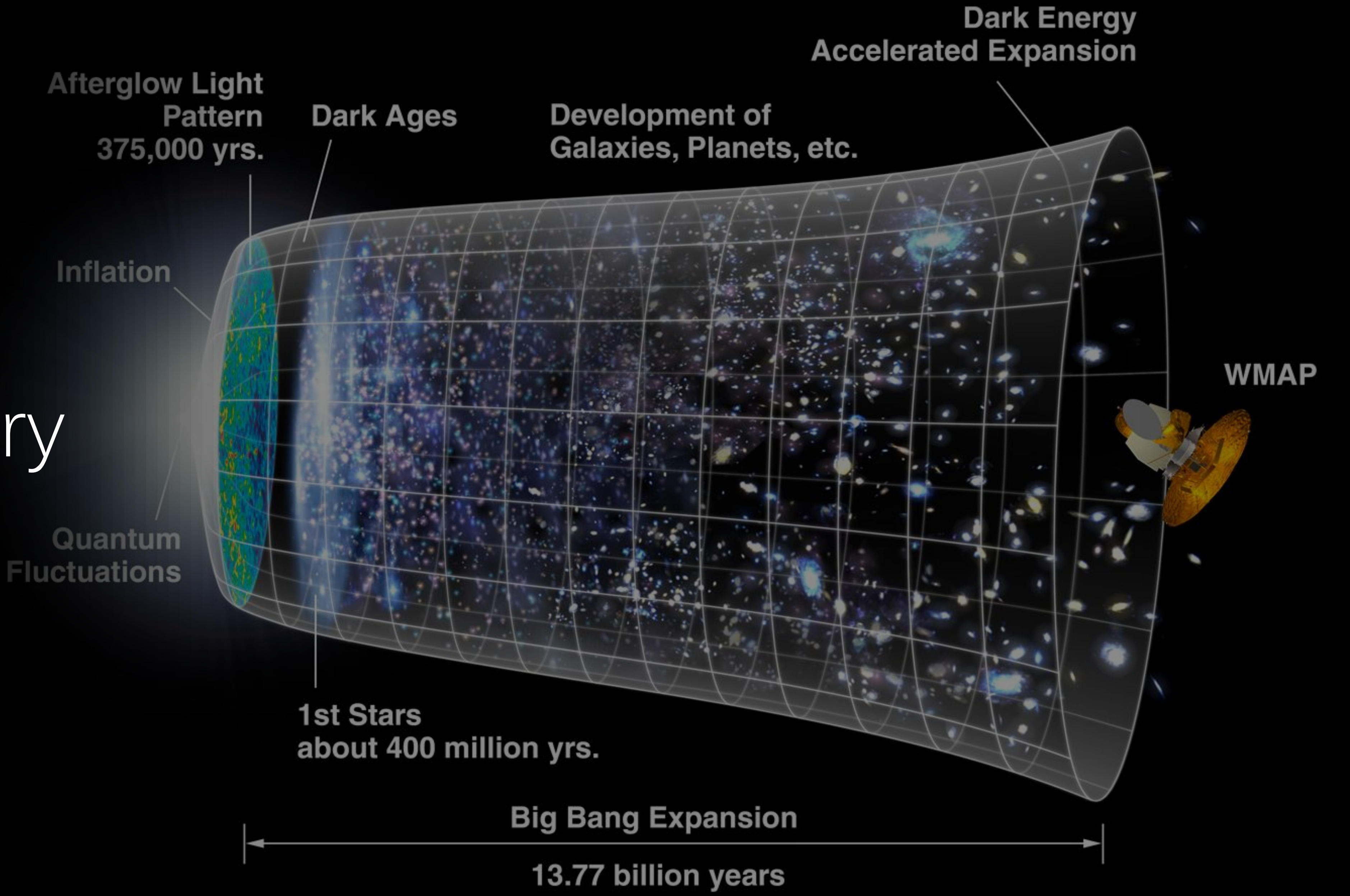
2. The tree-level story: cosmological reality

3. The loop-level story: Reality broken?

4. Unitarity renormalisation & universality

5. Summary & outlook

A brief history of time…



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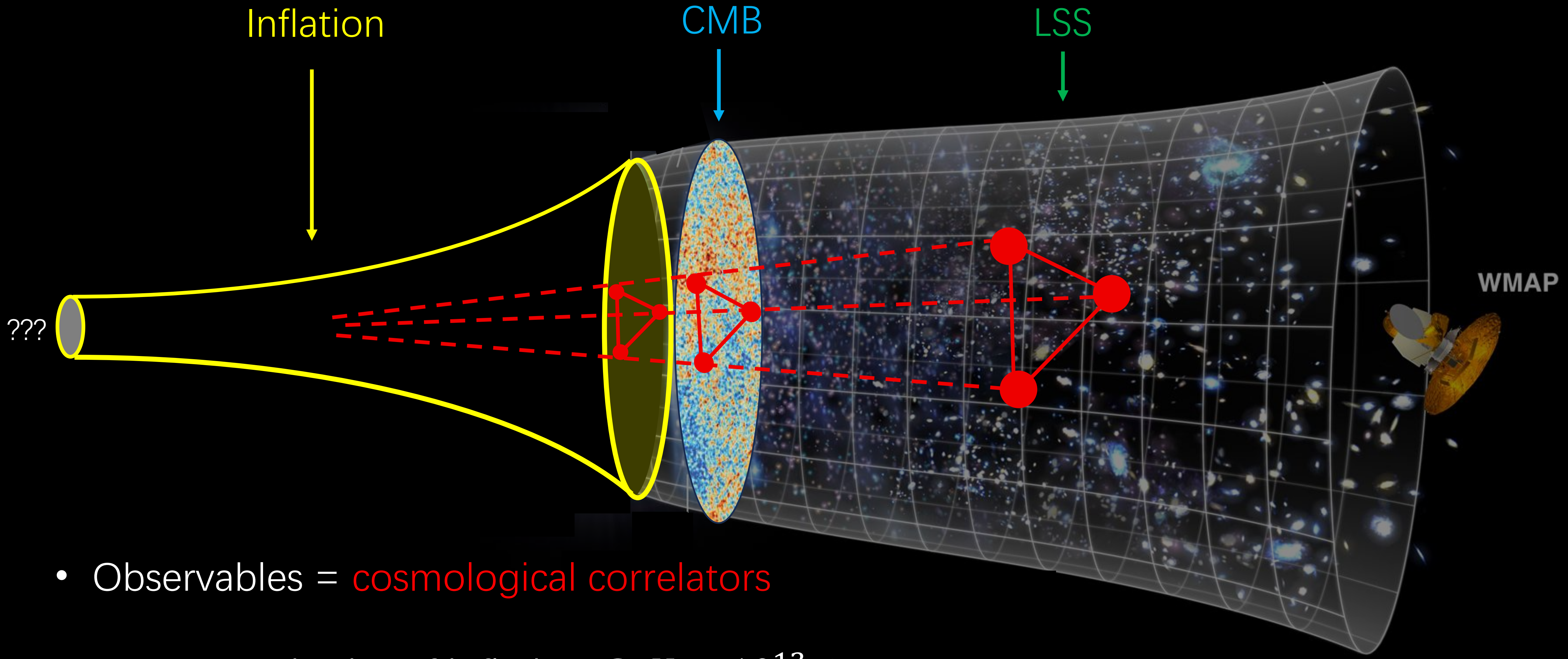

- Observables = cosmological correlators
- Targets = physics of inflation @ $H \leq 10^{13}$ GeV
  (DoFs, symmetries, fundamental principles, etc.)

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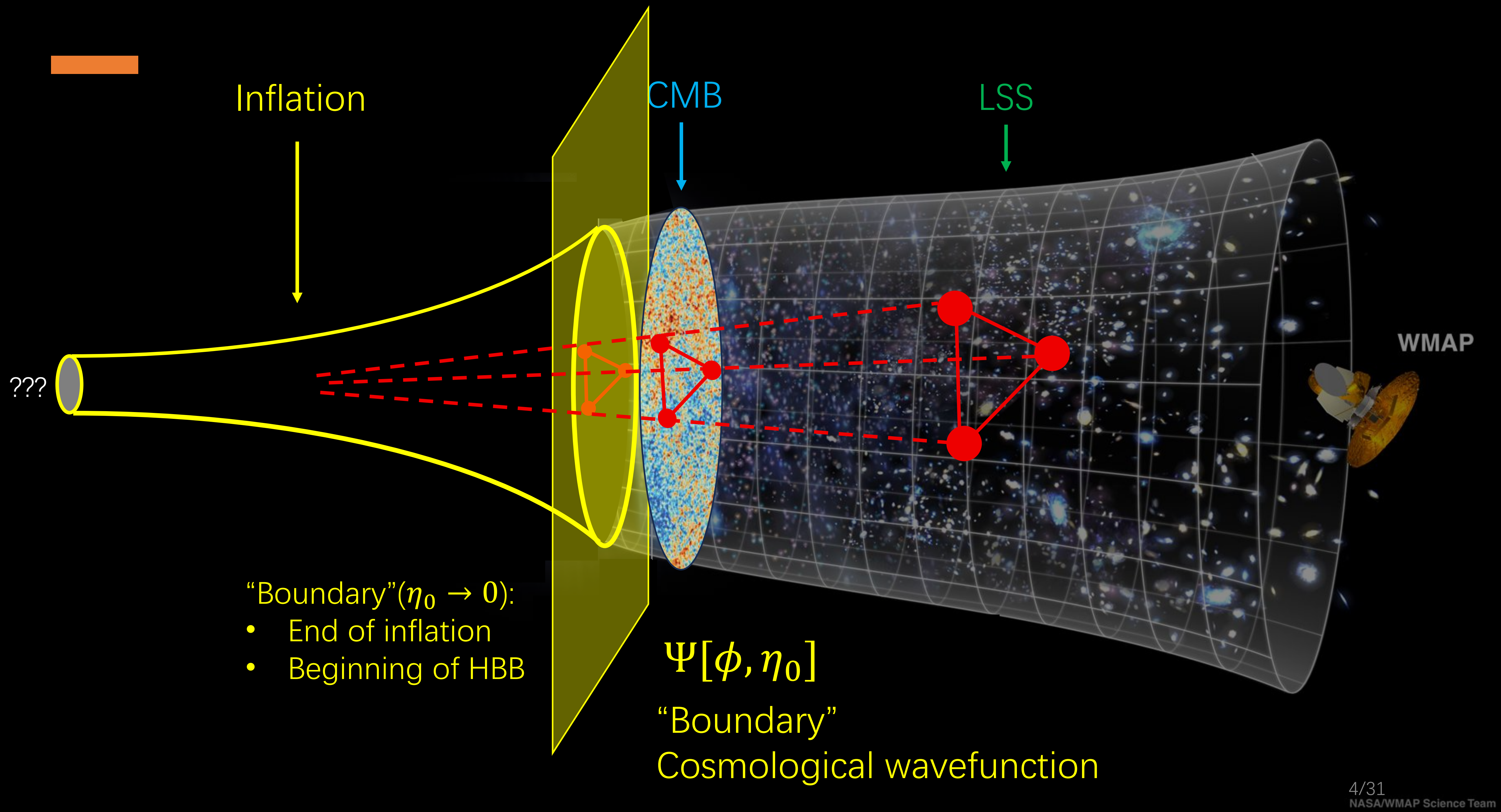
Inflation
CMB
LSS
???
WMAP
"Boundary"($\eta_0 \to 0$):
• End of inflation
• Beginning of HBB
$\Psi[\phi, \eta_0]$
"Boundary"
Cosmological wavefunction
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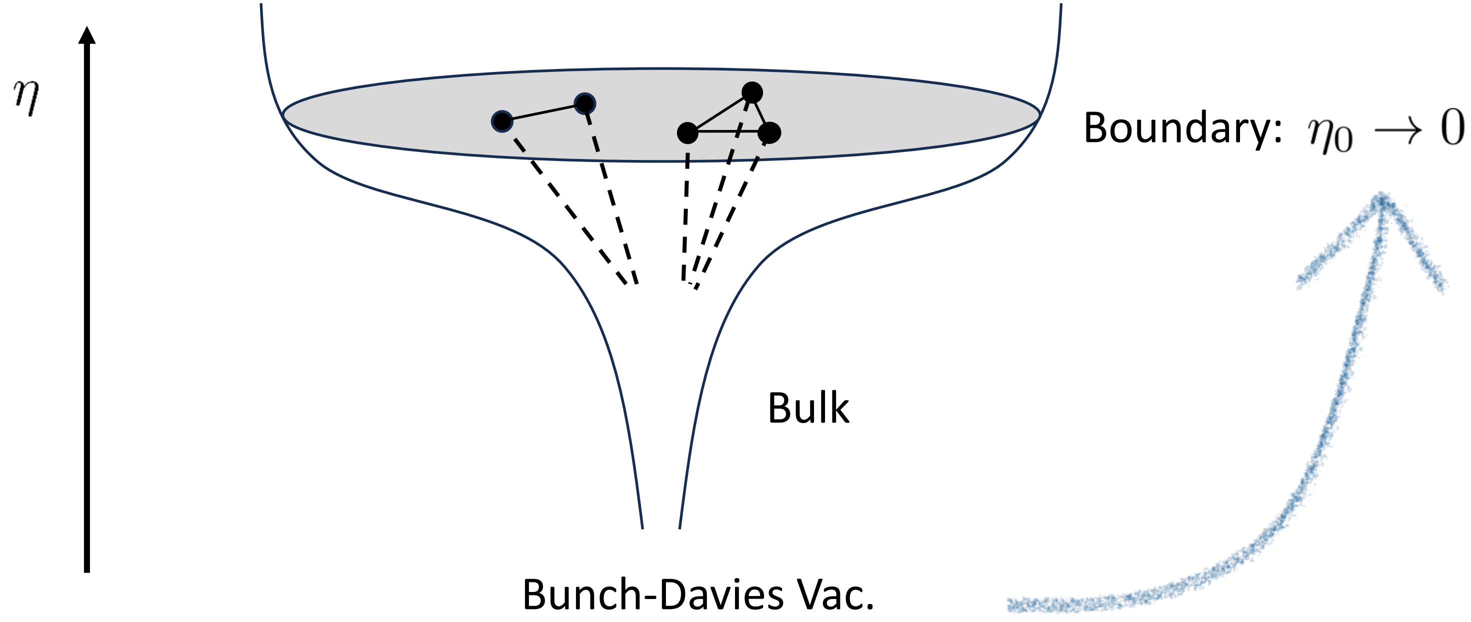
What is the cosmological wavefunction?



[Hartle & Hawking, 1983]
[Maldacena, 2002]
[Anninos et al., 2014]
[Many]

Cosmological wavefunction:

$$\Psi[\varphi] = \int_{\phi(-\infty)=\mathrm{BD}}^{\phi(\eta_0)=\varphi} \mathcal{D}\phi\, e^{iS[\phi]}$$

- No (non-perturbative) quantum gravity
- $i\epsilon$-prescription at $\eta \to -\infty$
- IR cutoff at $\eta_0 \to 0^-$

Correlators:

$$\langle \varphi(\mathbf{k}_1) \cdots \varphi(\mathbf{k}_n) \rangle = \frac{\int \mathcal{D}\varphi \left|\Psi[\varphi]\right|^2 \varphi(\mathbf{k}_1) \cdots \varphi(\mathbf{k}_n)}{\int \mathcal{D}\varphi \left|\Psi[\varphi]\right|^2}$$

How to compute them?

[Anninos et al., 2014]

$$\Psi[\varphi] = \int_{\phi(-\infty)=\mathrm{BD}}^{\phi(\eta_0)=\varphi} \mathcal{D}\phi\, e^{iS[\phi]} = e^{iS[\phi_{\mathrm{cl}}]} \times \int_{\delta\phi(-\infty)=\mathrm{BD}}^{\delta\phi(\eta_0)=0} \mathcal{D}\delta\phi\, e^{i(S[\phi_{\mathrm{cl}}+\delta\phi]-S[\phi_{\mathrm{cl}}])}$$

"Classical" saddle

$$\delta S|_{\phi=\phi_{\mathrm{cl}}} = 0\ ,\ \ \phi_{\mathrm{cl}}(\eta_0) = \varphi$$

"Quantum" correction

Perturbative *diagrammatics*

Trees

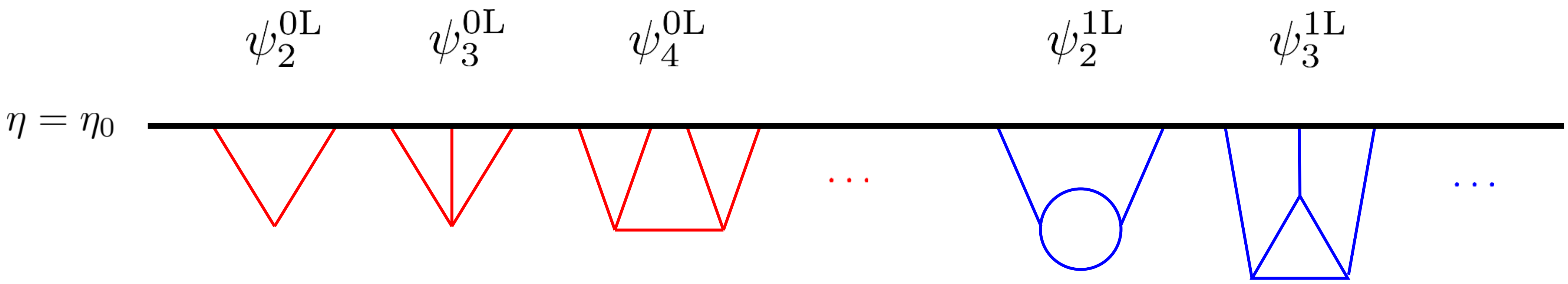
Loops

$\eta = \eta_0$

How to compute them?

n-point wavefunction coefficients

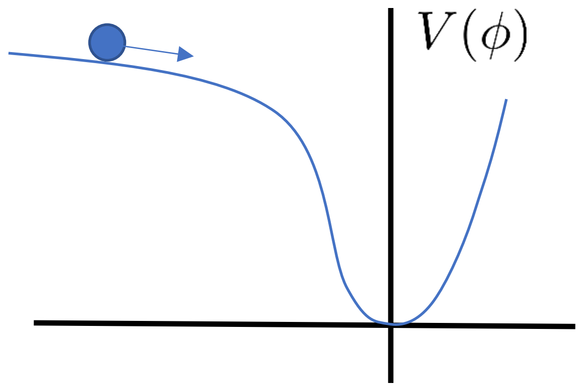
$$\Psi[\varphi] = \exp\left[+\sum_{n=1}^{\infty} \frac{1}{n!} \int_{\{\mathbf{k}\}} \psi_n(\mathbf{k}_1, \cdots, \mathbf{k}_n)\, \varphi(\mathbf{k}_1) \cdots \varphi(\mathbf{k}_n)\right]$$



A minimal set up

- Single-field slow-roll inflation

$$S = \int \mathrm{d}^4x\sqrt{-g}\left[\frac{1}{2}M_p^2 R - \frac{1}{2}(\partial\phi)^2 - V(\phi) + \mathcal{L}_{\rm int}\right]$$



- Quasi-de Sitter (dS) background

$$\mathrm{d}s^2 = a^2(\eta)\left(-\mathrm{d}\eta^2 + \mathrm{d}\mathbf{x}^2\right) \quad \text{with} \quad a(t) = e^{Ht} = -\frac{1}{H\eta}$$

- A single massless scalar DoF with (***IR convergent***) self-interactions

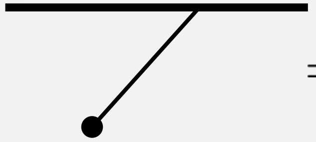
$$\mathcal{L}_{\rm int} = \mathcal{L}_{\rm int}(\partial\phi, \partial^2\phi, \cdots) = \frac{\lambda}{3!}\dot{\phi}^3 + \cdots$$

(Isolate the ***sub-horizon*** physics)

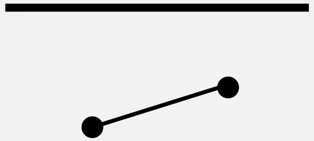
Shift symmetric

Simple examples @ tree level

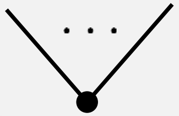
- Feynman rules:



$$= K_k(\eta) = (1 - ik\eta)e^{ik\eta}$$



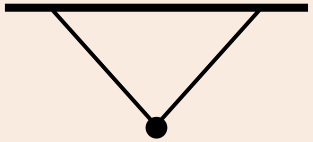
$$\begin{aligned} &= G_k(\eta_1, \eta_2) \\ &= \frac{iH^2}{k^3}(k\eta_1 \cos k\eta_1 - \sin k\eta_1) \\ &\quad \times (1 - ik\eta_2)e^{ik\eta_2}\theta(\eta_1 - \eta_2) \\ &\quad + (\eta_1 \leftrightarrow \eta_2) \end{aligned}$$



$$= i\int_{-\infty(1-i\epsilon)}^{0} \frac{\mathrm{d}\eta}{(-H\eta)^4}\mathcal{L}_{\text{int}}(\eta\partial_\eta, -i\mathbf{k}\eta)$$

- 2pt contact e.g. $\mathcal{L}_{\text{int}} \supset \frac{g}{2}\ddot{\phi}^2$

$\psi_2^{0\text{L}} =$



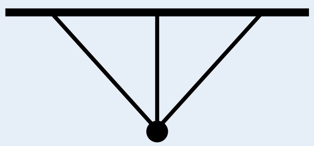
$$\begin{aligned} &= ig\int_{-\infty}^{0} \frac{\mathrm{d}\eta}{(-H\eta)^4}[(H\eta\partial_\eta)^2 K_k(\eta)]^2 \\ &= \frac{5g}{4}k^3 \end{aligned}$$

⇒ Correction to the power spectrum

More examples

- 3pt contact e.g. $\mathcal{L}_{\rm int} \supset \frac{\lambda}{3!}\dot{\phi}^3$

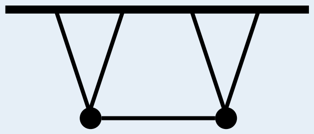
$$\psi_3^{\rm 0L} =$$



$$= \frac{2\lambda}{H}\frac{(k_1k_2k_3)^2}{k_T^3}$$

- 4pt exchange

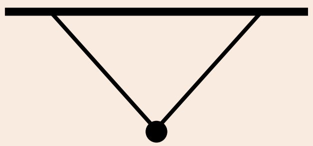
$$\psi_4^{\rm 0L} =$$



$$= \lambda^2(k_1k_2k_3k_4)^2\left[\frac{1}{k_T^5}\left(\frac{{\rm Poly}_3}{E_L^3}+\frac{{\rm Poly}_3}{E_R^3}\right)+\frac{2s}{E_L^3E_R^3}\right]$$

- 2pt contact e.g. $\mathcal{L}_{\rm int} \supset \frac{g}{2}\ddot{\phi}^2$

$$\psi_2^{\rm 0L} =$$



$$= ig\int_{-\infty}^{0}\frac{{\rm d}\eta}{(-H\eta)^4}[(H\eta\partial_\eta)^2K_k(\eta)]^2$$

$$= \frac{5g}{4}k^3$$

⇒ Correction to the power spectrum

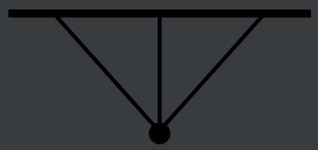
Technicalities aside, two highlights…

More examples @ tree level

1. Scale as $\psi_n \sim k^3$

- 3pt contact e.g. $\mathcal{L}_{\rm int} \supset \frac{\lambda}{3!}\dot{\phi}^3$

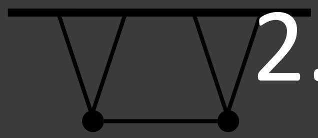
$\psi_3^{\rm 0L} =$



$$= \frac{2\lambda}{H}\frac{(k_1k_2k_3)^2}{k_T^3}$$

- 4pt exchange

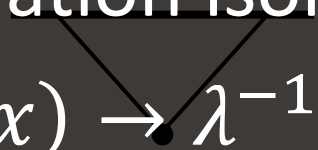
$\psi_4^{\rm 0L} =$



$$= \lambda^2(k_1k_2k_3k_4)^2\left[\frac{1}{k_T^5}\left(\frac{\text{Poly}_3}{E_L^3}+\frac{\text{Poly}_3}{E_R^3}\right)+\frac{2s}{E_L^3E_R^3}\right]$$

- 2pt contact e.g. $\mathcal{L}_{\rm int} \supset \frac{g}{2}\ddot{\phi}^2$

$\psi_2^{\rm 0L} =$



$$= ig\int_{-\infty^+}^{0}\frac{d\eta}{(-H\eta)^4}[(H\eta\partial_\eta)^2K_k(\eta)]^2$$

$$= \frac{5g}{4}k^3$$

→ Correction to the power spectrum

- dS dilation isometry (scale inv.):

$$(\eta, x) \to \lambda^{-1}(\eta, x)$$

$$k \to \lambda\, k$$

2. Purely ***real***: $\text{Im}\,\psi_n^{\rm 0L} = 0$

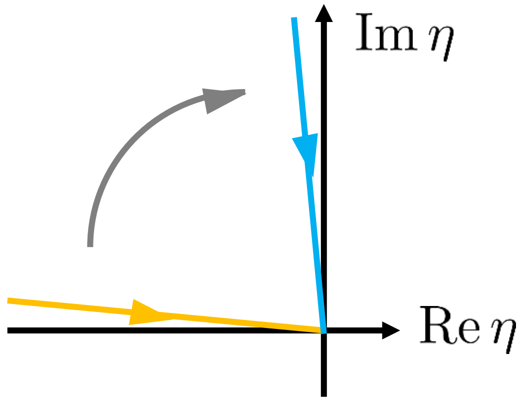
- ***Why***?

Why the reality?

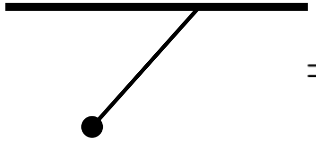
BD vac = Euclidean vac

+ locality

Wick rotation $\eta = i\chi$

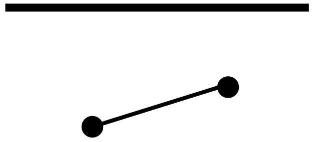


- Feynman rules:



$= K_k(\eta) = (1 - ik\eta)e^{ik\eta}$

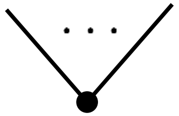
$K_k(i\chi) \in \mathbb{R}$



$= G_k(\eta_1, \eta_2)$

$= \frac{iH^2}{k^3}(\cos k\eta_1 - \sin k\eta_1) \times (1 - ik\eta_2)e^{ik\eta_2}\theta(\eta_1 - \eta_2) + (\eta_1 \leftrightarrow \eta_2)$

$G_k(i\chi_1, i\chi_2) \in \mathbb{R}$



$= i\int_{-\infty(1-i\epsilon)}^{0} \frac{d\eta}{(-H\eta)^4} \mathcal{L}_{\rm int}(\eta\partial_\eta, -i\mathbf{k}\eta)$

$\mathcal{L}_{\rm int}(\chi\partial_\chi, \mathbf{k}\chi) \in \mathbb{R}$

(Unitarity & scale inv.)

Cosmological ***reality*** theorem

$$\text{Im}\,\psi_n^{0\text{L}} = 0$$

[Liu, **Tong**, Wang & Xianyu, 2019]
[Stefanyszyn, **Tong** & Zhu, 2023]

- Any IR-conv. ints
- Any light bulk fields of any integer spin
- Boost-breaking effects (e.g. non-unit sound speed)

Now, what does this cosmological reality imply?

Why the reality matters?

Parity

- A real field: $$\varphi(\mathbf{x}) = \int_{\mathbf{k}} e^{i\mathbf{k}\cdot\mathbf{x}}\varphi(\mathbf{k})$$

Parity = c.c. in momentum space

$$\varphi^*(\mathbf{x}) = \varphi(\mathbf{x}) \quad \Longleftrightarrow \quad \varphi^*(\mathbf{k}) = \varphi(-\mathbf{k})$$

- Parity-odd = imaginary

$$\langle\varphi(\mathbf{k}_1)\cdots\varphi(\mathbf{k}_n)\rangle^{\mathrm{PO}} = i\,\mathrm{Im}\,\langle\varphi(\mathbf{k}_1)\cdots\varphi(\mathbf{k}_n)\rangle$$

$$\propto \mathrm{Im}\,\left(\psi_n^{0\mathrm{L}} + \text{lower points}\right)$$

Cosmological reality $\downarrow$

$$= 0$$

A no-go theorem on parity violation

- Unitarity & locality
- Scale inv.
- BD vac.
- Tree

No PV correlators

$$\langle\varphi(\mathbf{k}_1)\cdots\varphi(\mathbf{k}_n)\rangle^{\text{PO}} = 0$$

in massless scalar EFTs

[Liu, **Tong**, Wang & Xianyu, 2019]
[Cabass, Jazajeri, Pajer & Stefanyszyn, 2022]

Generalisable to

- Higher spins
- Other dimensions

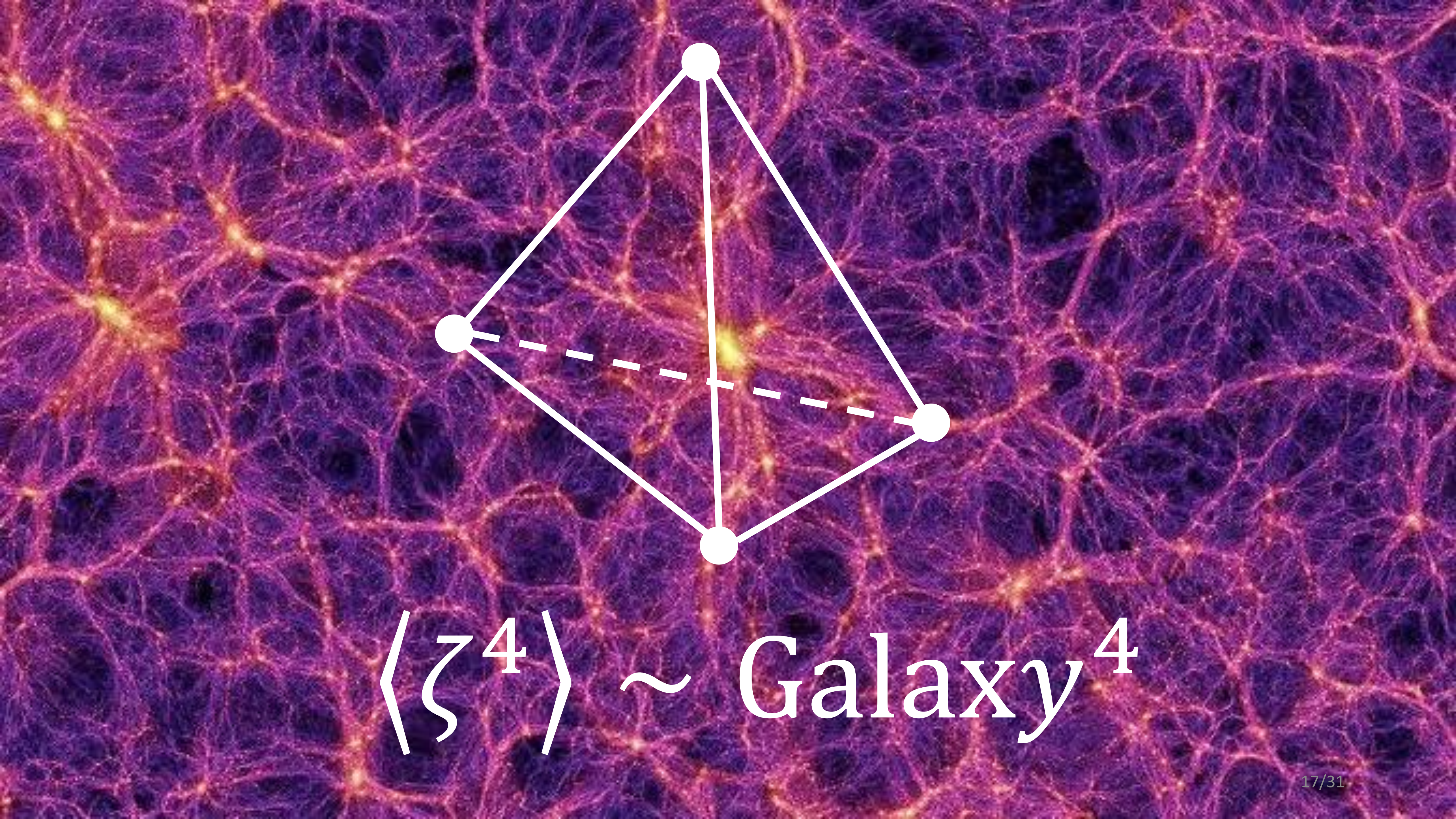
[Cabass, Jazajeri, Pajer & Stefanyszyn, 2022]
[Goodhew, Thavanesan & Wall, 2024]
[Thavanesan, 2025]

➢ Most general massless scalar EFT (PV: $\text{dim} \geq 10$):

$$\mathcal{L}_{\text{int}} = \frac{g}{2}\ddot{\phi}^2 + \cdots + \frac{\lambda}{3!}\dot{\phi}^3 + \cdots + c_{10}\epsilon_{ijk}\phi\partial_i\phi\partial_j\dot{\phi}\partial_k\partial^2\phi + \cdots$$

dynamical but ***invisible***

➢ A ***null test*** on the fundamental principles


$\langle \zeta^4 \rangle \sim \text{Galaxy}^4$

PV @ the observational frontier

Parity in Composite-Field Galaxy Correlators

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[c]Kavli Institute for Cosmology Cambridge, Madingley Road, Cambridge, CB3 0HA, UK
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Abstract. Detecting parity violation on cosmological scales would provide a striking clue to new physics. Large-scale structure offers the raw statistical power—many three-dimensional modes—to make such tests. However, for scalar observables, like galaxy clustering, the leading parity-sensitive observable is the trispectrum, whose high dimensionality makes the measurement and noise estimation challenging. We present two late-time parity-odd kurto spectra that compress the parity-odd scalar trispectrum into one-dimensional, power–spectrum–like observables. They are built by correlating (i) two appropriately weighted quadratic composite fields, or (ii)

Measurement of Parity-Odd Mode
4-Point Correlation Function of SD

Testing Parity Symmetry with the Polarized Cosmic Microw

Oliver H.E. Philcox[1,2,*] and Maresuke Shiraishi[3,†]
[1]Center for Theoretical Physics, Department of Physics, Columbia University, New York, NY 10027, USA

Probing Parity-Violation w

Measurement of Parity-Violating Modes of the Dark Energy Spectroscopi
Instrument (DESI) Year 1 Luminous Red Galaxies' 4-Point Correlation Func

Zachary Slepian,[1] Alex Krolewski,[2,3] Alessandro Greco,[1] Simon May,[4] William Ortolá Leonard,[5] Far Kamalinejad,[5] Jessica Chellino,[1] Matthew Reinhard,[5] Elena Fernandez,[6] Francisco Prada,[6] Steven Ahlen, Bianchi,[8,9] David Brooks,[10] Todd Claybaugh,[11] Axel de la Macorra,[12] Arnaud de Mattia,[13] Biprateep De Peter Doel,[10] Enrique Gaztañaga,[17,18,19] Gaston Gutierrez,[20] Klaus Honscheid,[21,22] Dragan Huterer,[23] Dic Robert Kehoe,[25] David Kirkby,[26] Theodore Kisner,[11] Martin Landriau,[11] Laurent Le Guillou,[27] Marc Ma Aaron Meisner,[24] Ramon Miquel,[30,29] Seshadri Nadathur,[18] Will Percival,[2,4,3] Ashley Ross,[21,22] Eusebio Sanchez, David Schlegel,[11] Michael Schubnell,[23] Hee-Jong Seo,[32] Joseph Silber,[11] David Sprayberry,[24] and Gregory Tarlé[23]
Affiliations are given after the Appendix.

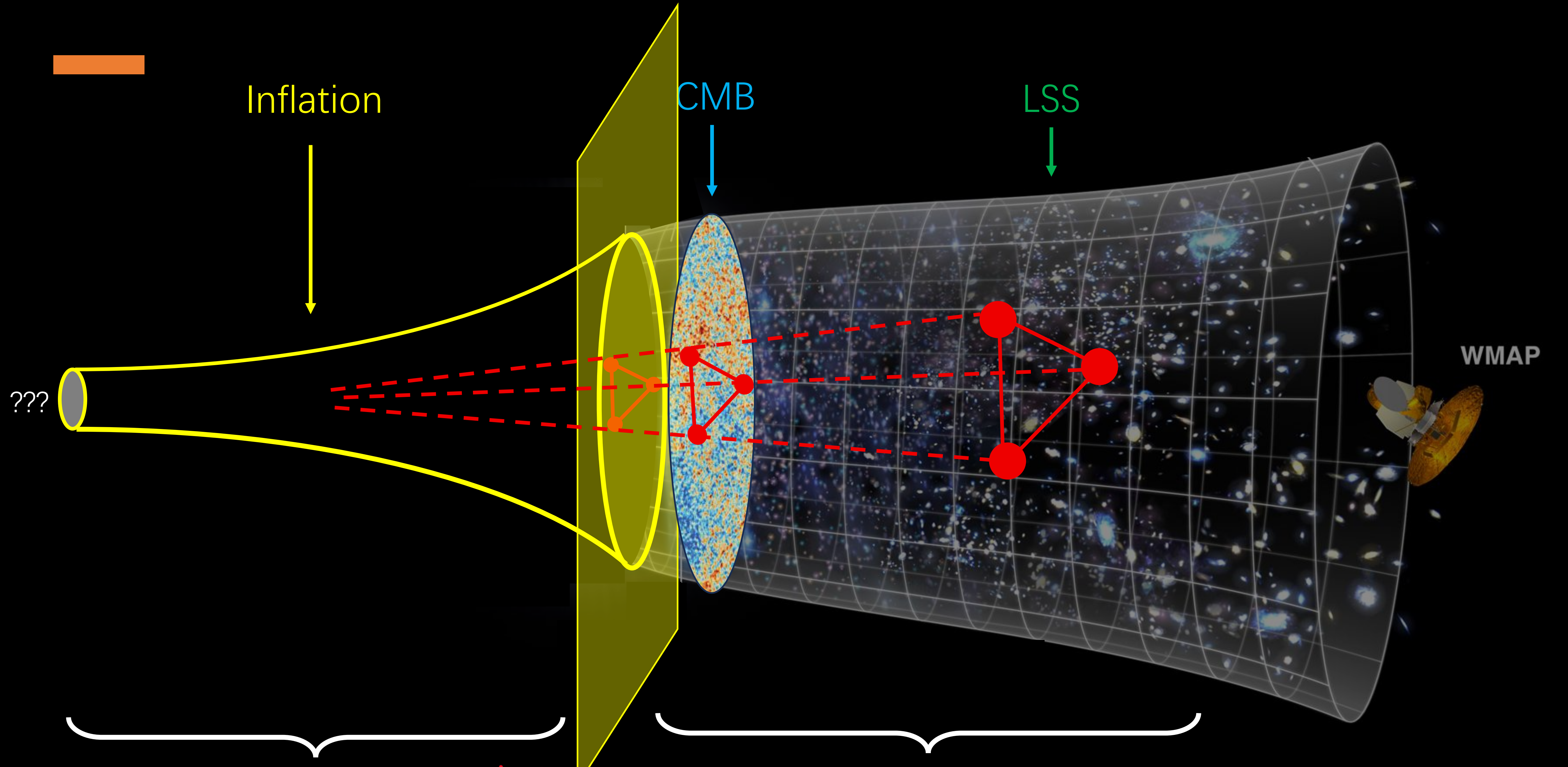
Here we report the first measurement of the parity-violating (PV) 4-Point Correlation Function (4PCF) of the Dark Energy Spectroscopic Instrument's Year 1 Luminous Red Galaxy (DESI Y1 LRG) sample, motivated by the potential detection of the PV 4PCF in the Sloan Digital Sky Survey Baryon Oscillation Spectroscopic Survey (SDSS BOSS) galaxies. In our auto-correlation ("auto") analysis, we find a statistically significant excess of the PV signal compared to mocks without any

- Evidence for PV scalar trispectrum?
- Likely systematics…☹
- Yet more analysis and new probes coming ☺

[Hou, Slepian & Cahn, 2022]
[Philcox, 2022]
[Philcox & Shirashi, 2023]
[Many]
[Slepian et al., 2025]
[Gao, Dizgah & Vlah, 2025]

- ✓ Cosmo PV is growingly active.

- ✓ and *important*…



- ☐ ***Unknown*** & quantum (parity)
- ✓ ***Known*** classical physics (parity)

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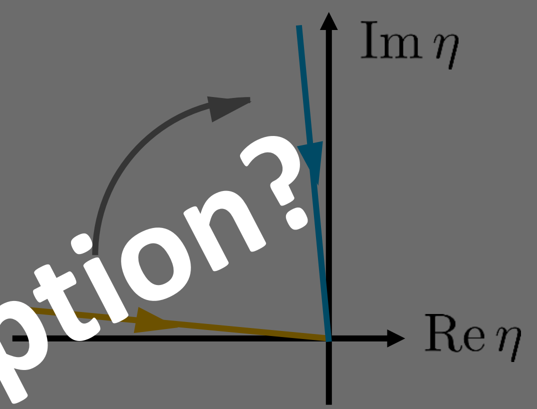
What more from the theory side?

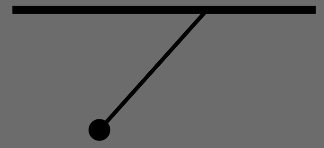
Where's the "tree" assumption?

BD vac = Euclidean vac

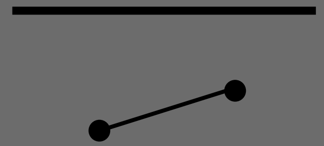
+ locality

Wick rotation $\eta = i\chi$

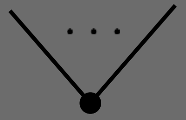




$K_k(i\chi) \in \mathbb{R}$



$G_k(i\chi_1, i\chi_2) \in \mathbb{R}$



$\mathcal{L}_{\text{int}}(\chi\partial_\chi, \mathbf{k}\chi) \in \mathbb{R}$

(Unitarity & scale inv.)

Cosmological ***reality*** theorem

$$\text{Im}\,\psi_n^{0\text{L}} = 0$$

How about loops?

- At 1 loop:

Manifestly real after Wick rot. $\eta = i\chi$

$$\psi_n^{1\mathrm{L}} = \int \frac{\mathrm{d}^3\mathbf{q}}{(2\pi)^3} \int_{-\infty}^{0} \left[\prod_{v=1}^{V} i\,\mathrm{d}\eta_v f_v(\eta\partial_\eta, -i\mathbf{k}\eta)\right] \left[\prod_{e=1}^{n} K_e(\eta_e, k_e)\right] \left[\prod_{\mathrm{i}=1}^{I} G_e(\eta_\mathrm{i}, \eta'_\mathrm{i}, q_\mathrm{i})\right] = \mathrm{Real?}$$

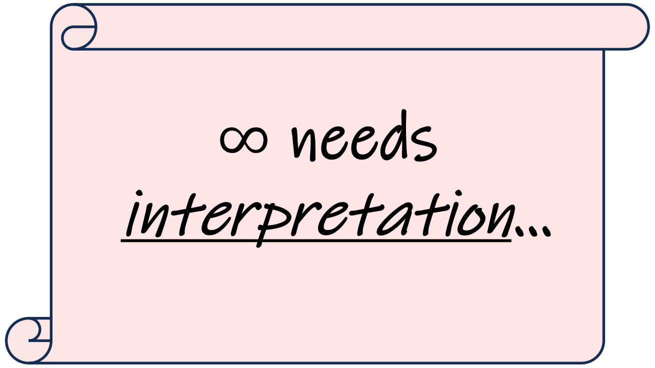
Careful: UV div. !

- A divergent integral of real numbers may not be real anymore…

$$(+\infty)^* - (+\infty) = 0?$$

- Classic example:

$$1 + 2 + 3 + \cdots \to -\frac{1}{12}$$



A glimpse of the breaking of reality

- (η-) regularisation:

[Padilla & Smith, 2024,2024]
(Minkowski)

$$\int \frac{\mathrm{d}^3\mathbf{q}}{(2\pi)^3} \to \int \frac{\mathrm{d}^3\mathbf{q}}{(2\pi)^3} \times \eta\left(\frac{\mathbf{q}}{\Lambda}\right)$$

$\eta(\infty) \to 0$

Not necessarily real

- In mass-dim reg. ($d = 3 - \epsilon,\quad m_\phi^2 = -\frac{3}{2}\epsilon\, H^2$)

[Lee, McCulloch & Pajer, 2023]
Phase formula in [Goodhew, Thavanesan & Wall, 2024]

$$\int \frac{\mathrm{d}^3\mathbf{q}}{(2\pi)^3} \times (i|\mathbf{q}|\eta_0)^{d-3} \sim \frac{1}{\epsilon} \times i^{\epsilon} \sim \frac{1}{\epsilon} + \frac{i\pi}{2} + \cdots$$

☐ An emergent imaginary part !?

- However, artificial?

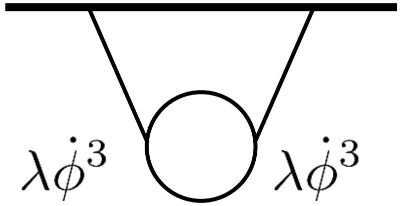
$$\int \frac{\mathrm{d}^3\mathbf{q}}{(2\pi)^3} \times e^{-\frac{e^{i\theta}|\mathbf{q}|}{\Lambda}} \sim \log\Lambda - i\theta$$

☐ Reg-dependent ???

Counterterms can't solve the issue

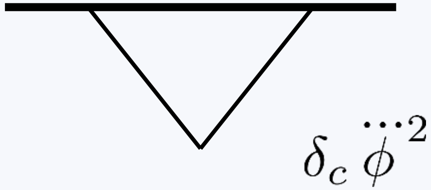
- Renormalisation

$$\widehat{\psi}_2^{1L} = \psi_2^{1L} + \psi_2^{ct}$$



$$\psi_2^{1L} = \frac{\lambda^2 H^2}{16} k^3 \int \frac{d^3 q_1}{(2\pi)^3} q_1 q_2 \frac{3q_+^2 + 9kq_+ + 8k^2}{k^4 (k+q_+)^3} \eta\left(\frac{q_+}{\Lambda}\right)$$

$$= \frac{1}{15}\frac{\lambda^2 H^2}{(4\pi)^2} k^3 \left(\log\frac{\Lambda}{H} + i\theta\right)$$



$$\frac{1}{15}\frac{\lambda^2 H^2}{(4\pi)^2} k^3 \left(-\log\frac{\Lambda}{H}\right)$$

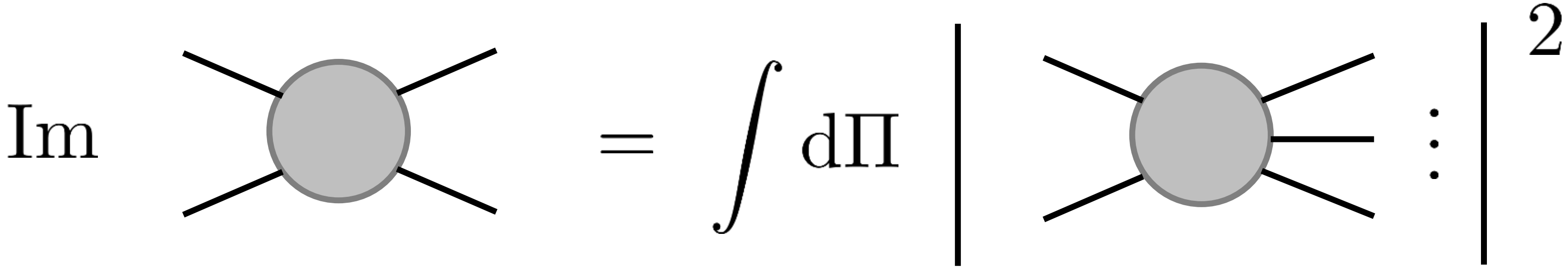
Real by tree reality

⇩

Hermitian counterterms ***cannot*** alter the imaginary part

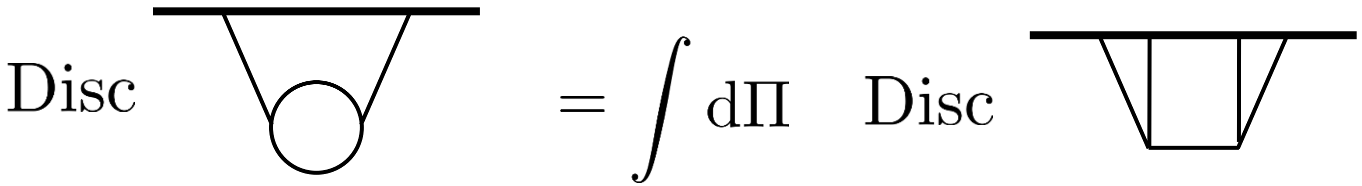
Unitarity to the rescue

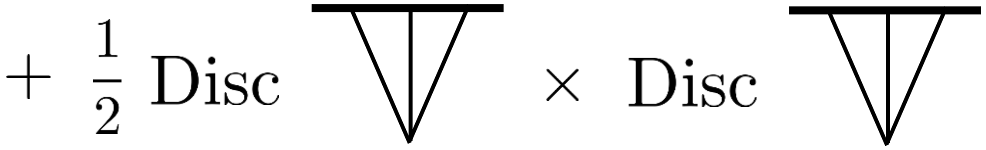
- In *Minkowski QFTs*, arbitrary imaginary terms are forbidden by the ***Optical Theorem (OT)***



- In *dS QFTs*, ***no*** strict OT, but a perturbative ***Cosmological Optical Theorem (COT)***

[Goodhew, Jazayeri & Pajer, 2020]
[Melville & Pajer, 2021]

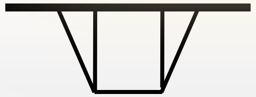


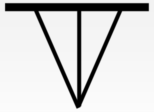
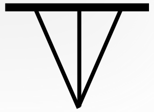


$\int$:

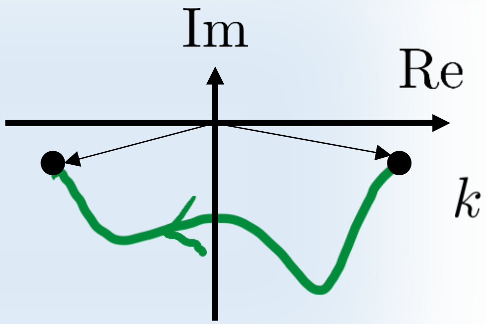
- Identity for the integrand
- Commuting Disc outside requires (!)

$$\mathrm{Disc}\int \frac{\mathrm{d}^3\mathbf{q}}{(2\pi)^3}\times \eta(\mathbf{q};k)=0$$

Disc  $= \int \mathrm{d}\Pi$ Disc 

$+\ \frac{1}{2}$ Disc  $\times$ Disc 

Disc :



$-k^* = -|k| - i\epsilon$

$k = |k| - i\epsilon$

$$\mathrm{Disc}\, f \equiv f(k) - [f(-k^*)]^*$$

Not any reg goes…

COT (unitarity)

Scale inv.

Analyticity

⇒

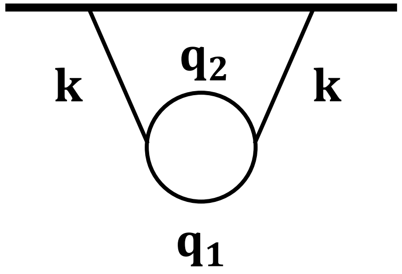
<u>Unitary & analytic</u> η-regs

$$\eta = \rho\left(\frac{q}{ik}\Big/\frac{\Lambda}{H}\right)$$

$$\rho(0) = 1\ ,$$

$$\rho(\infty e^{i\alpha}) = 0\ ,\ -\frac{\pi}{2} < \alpha < \frac{\pi}{2}$$

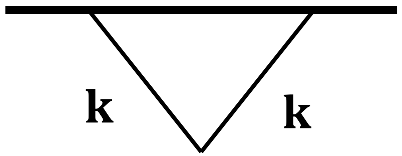
The breaking of cosmological reality



$$= \frac{\lambda^2 H^2}{16} k^3 \int \frac{\mathrm{d}^3 q_1}{(2\pi)^3} q_1 q_2 \frac{3q_+^2 + 9kq_+ + 8k^2}{k^4 (k+q_+)^3} \rho\left(\frac{q_+/k}{i\Lambda/H}\right)$$

$$= \frac{\lambda^2 H^2}{15(4\pi)^2} k^3 \left[\frac{45}{64} C_4[\rho] \left(\frac{\Lambda}{H}\right)^4 + \frac{45}{64} C_2[\rho] \left(\frac{\Lambda}{H}\right)^2 + \left(\log\frac{\Lambda}{H} + \frac{i\pi}{2} + \gamma[\rho] + \frac{45}{256}\right) + \cdots \right]$$

Add *counterterms*:



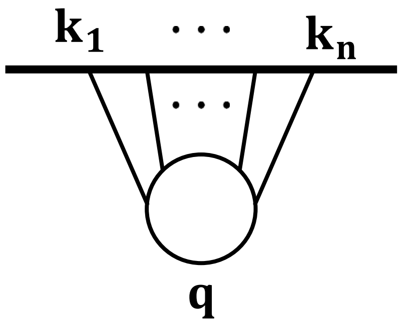
$$= \frac{\lambda^2 H^2}{15(4\pi)^2} k^3 \left[-\frac{45}{64} C_4[\rho] \left(\frac{\Lambda}{H}\right)^4 - \frac{45}{64} C_2[\rho] \left(\frac{\Lambda}{H}\right)^2 - \left(\log\frac{\Lambda}{\mu} + \gamma[\rho] + \frac{45}{256}\right) \right]$$

$$\hat{\psi}_2^{1\mathrm{L}} = \psi_2^{1\mathrm{L}} + \psi_2^{\mathrm{ct}} = \frac{\lambda^2 H^2}{15(4\pi)^2} k^3 \left(\log\frac{\mu}{H} + \frac{i\pi}{2}\right)$$

Emergent Im part from U & A !

Higher points and 1-loop universality

Real by tree-level reality



$$= \psi_n^{1L} = \int_{\min}^{\infty} \frac{dq_+}{q_+} f(\{k\},\{q\},\{\mathbf{k}\}) \times \rho\left(\frac{q_+/k_T}{i\Lambda/H}\right)$$

$$= \sum_{m=\text{even}} f_m C_m[\rho] \left(\frac{\Lambda}{H}\right)^m + f_0\left(\log\frac{\Lambda}{H} + \frac{i\pi}{2} + \gamma[\rho] + g_0\right) + \cdots$$

- A ***universal*** imaginary part for all 1-loop renormalised WFs:

$$\widehat{\psi}_n^{1L} = f_0\left(\log\frac{\mu}{H} + g_0 + \frac{i\pi}{2}\right)$$

Im fixed by U & A w.r.t. the log div.

Connection towards (UV) RG in dS?

$$\left(\mu\frac{\partial}{\partial\mu}-\frac{2}{\pi}\mathrm{Im}\right)\widehat{\psi}_n^{1\mathrm{L}}=0$$

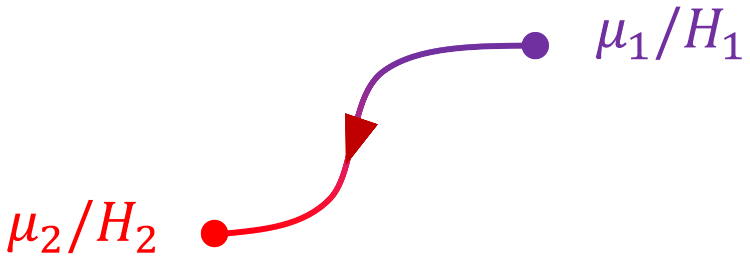
- Any 1-loop topologies
- Any bulk fields with ***integer spin*** and ***light mass***
- Any ***IR-conv.*** interactions
- Any U & A η-regs (***uncountably*** many)

Discussions:

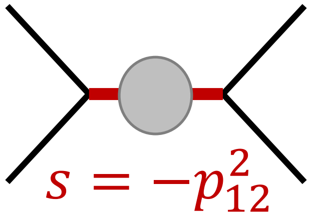
- Looks like Callan-Symanzik eq.

$$\left(\mu\frac{\partial}{\partial\mu}+\beta\frac{\partial}{\partial\lambda}+n\gamma\right)G_n=0$$

- (UV) RG flow in dS bulk?

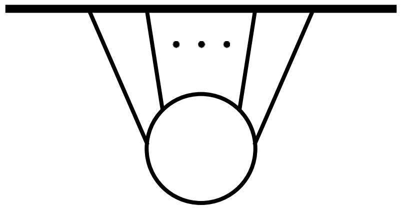
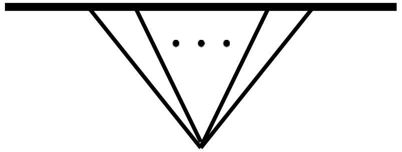


- What's the "energy-scale" variable?



$$\sim\log\frac{s}{\mu^2}$$

Checking with dim regs

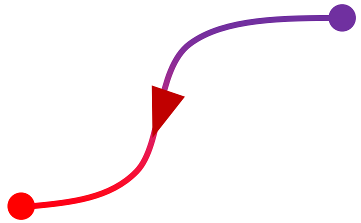
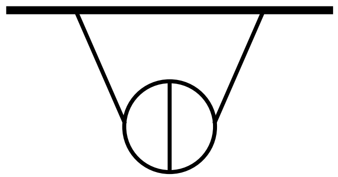
Imaginary part	ψ_n^{1L} 		ψ_n^{ct} 		
dim reg ($d = 3 - \epsilon,\ m_\phi^2 = 0$)	0	+	$\frac{i\pi}{2}$	=	$\mathrm{Im}\,\widehat{\psi}_n^{\mathrm{1L}} = \frac{\pi}{2}$
mass-dim reg ($d = 3 - \epsilon,\ m_\phi^2 = -\frac{3}{2}\epsilon H^2$)	$\frac{i\pi n}{4}$	+	$-\frac{i\pi(n-2)}{4}$	=	$\mathrm{Im}\,\widehat{\psi}_n^{\mathrm{1L}} = \frac{\pi}{2}$

Summary and outlooks

- ✓ Cosmological WF and correlators are useful
- ✓ WFs satisfy ***reality*** at tree level
- ✓ Translates to a no-go thrm. for PV with obs. consequences
- ✓ Yet spontaneously ***broken*** by UV divs loops
- ✓ By U & A, breaking is ***universal*** and hints at a connnection to RG in dS

$$\left(\mu\frac{\partial}{\partial\mu} - \frac{2}{\pi}\mathrm{Im}\right)\widehat{\psi}_n^{\mathrm{1L}} = 0$$

Summary and outlooks

- ☐ Connection to RG? → 
- ☐ Parity violation as a "scale anomaly"? → $\langle \phi^n \rangle_{\mathrm{PO}} = \frac{i\pi}{2} \mu \frac{\partial}{\partial \mu} \langle \phi^{n-1} \pi \rangle_{\mathrm{PO}}$?
- ☐ More on η reg in cosmology → $\eta(k_{\mathrm{IR}})$?
- ☐ Fermions and higher loops? → 
- ☐ Etc.

Thanks for your attention!