Effective field theory approach to quasi-single field inflation

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based on arXiv: 1211.1624

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(Tokyo Institute of Technology)

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Quasi-single field inflation

classification of inflation models w.r.t. relevant dof

	relevant dof
single field	adiabatic mode ζ (massless)
multiple field	adiabatic + isocurvatures

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- phenomenologically interesting (characteristic signatures in primordial perturbations)

QSI & non-Gaussianities

quasi-single field inflation [Chen-Wang '09]

massless field

$$\pi \equiv \frac{\delta\phi}{\dot{\phi}}$$

mixing

$\dot{\pi}\sigma$

massive field

σ

σ^3 coupling

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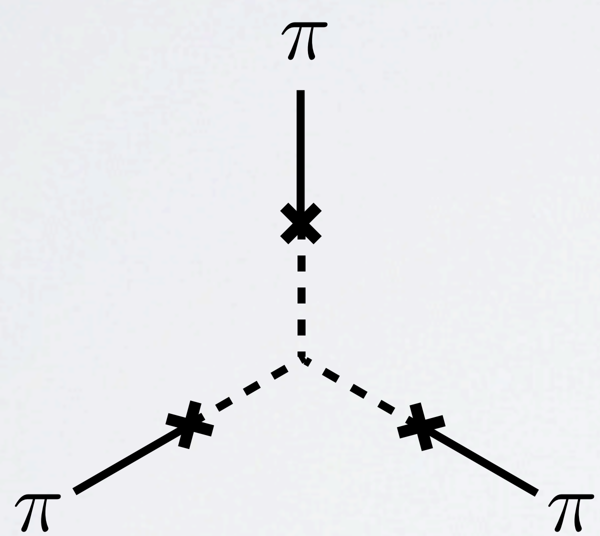

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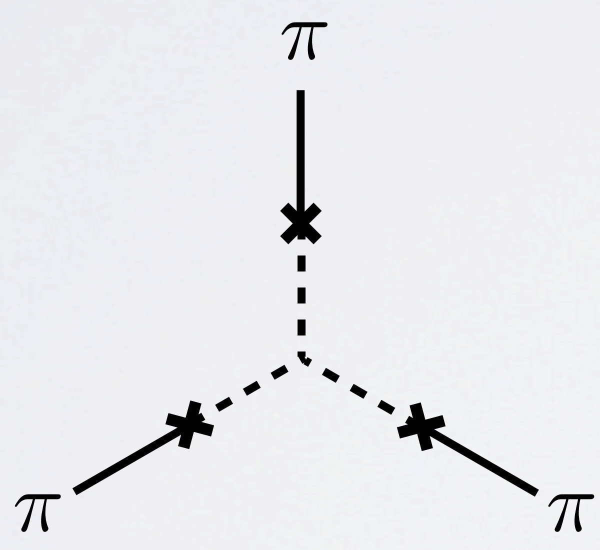

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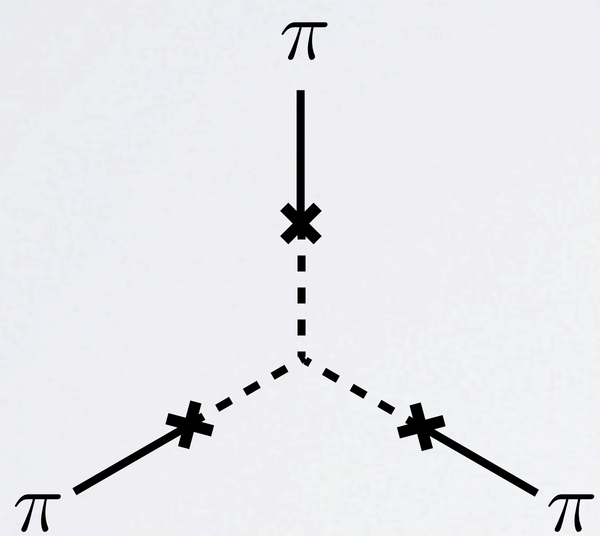

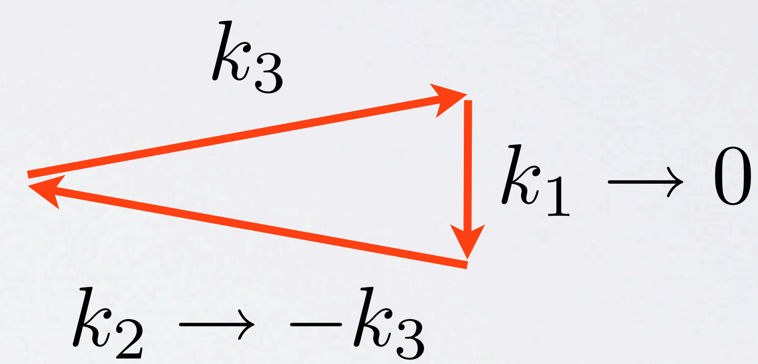

$$|k_2| = |k_3| = k, \; |k_1| = \kappa k$$

- intermediate shape between local and equilateral types
- characteristic scaling in squeezed limit

$$\langle \pi_{k_1} \pi_{k_2} \pi_{k_3} \rangle \propto \kappa^{-3/2-\nu} k^{-6} \qquad \nu = \sqrt{9/4 - m_\sigma^2/H^2}$$

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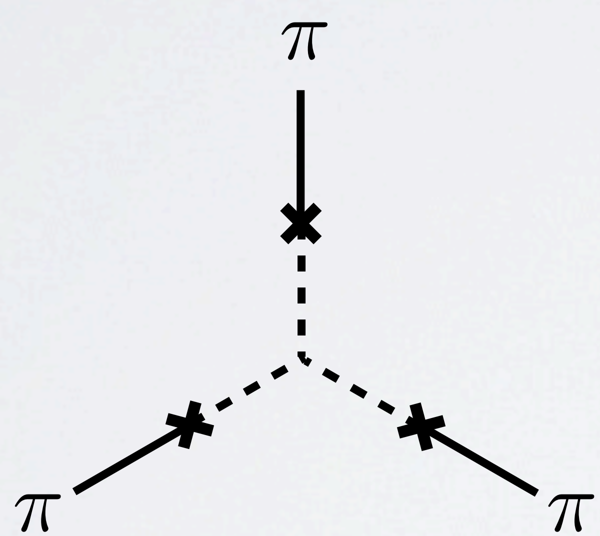

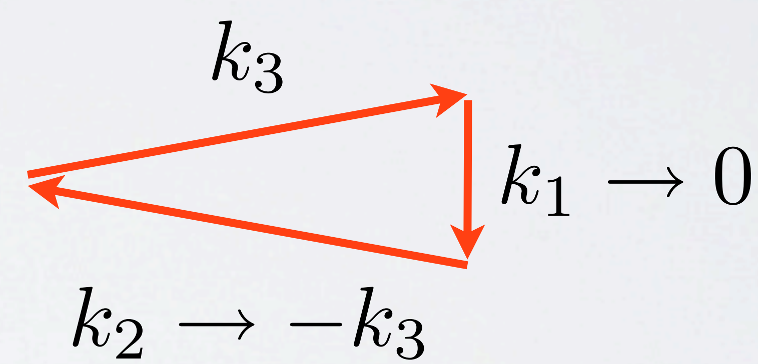

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effective field theory approach!

EFT approach

effective field theory approach [Cheung et al '07]

time dependent background evolution during inflation

(time-dependent vev: $R(t)$, $\phi_0(t)$)

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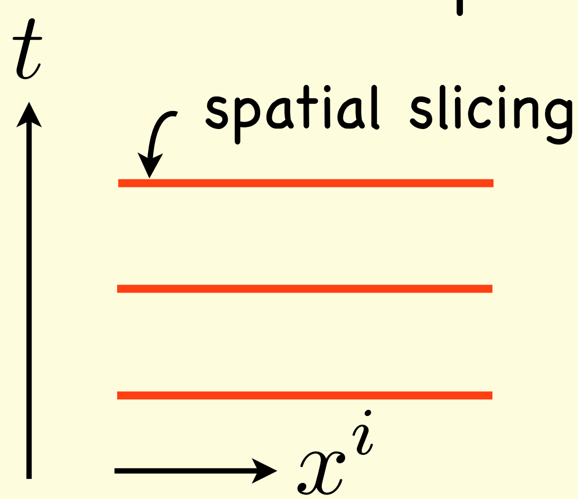

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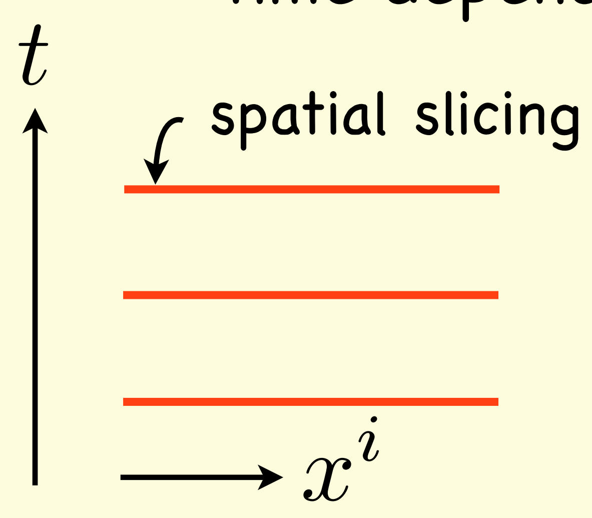

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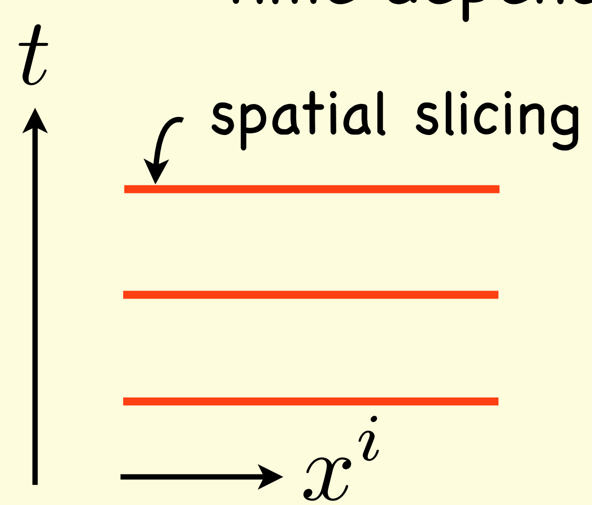

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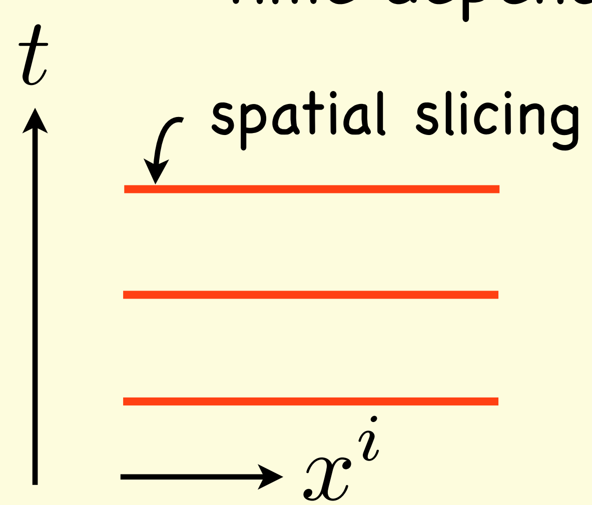

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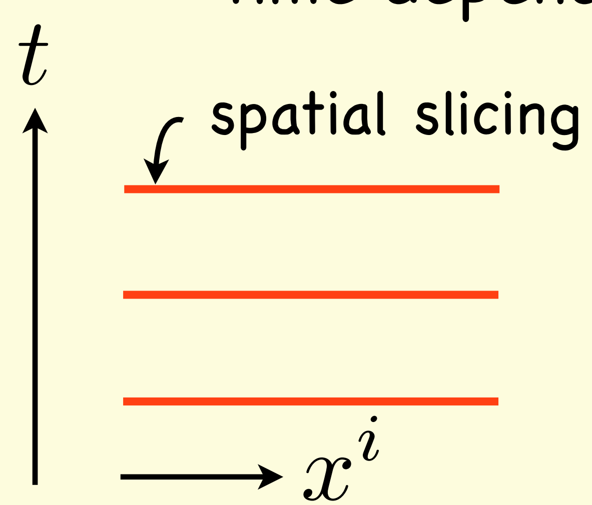

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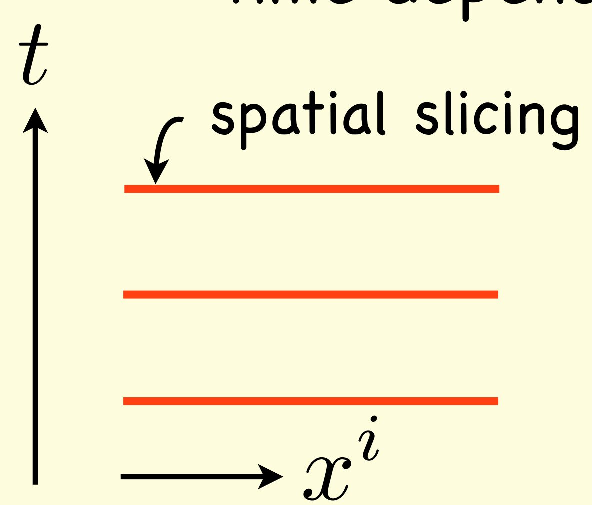

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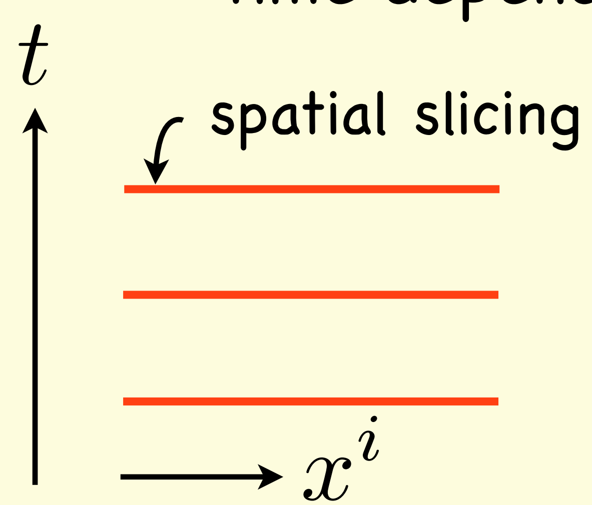

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advantages:

- systematic expansions in fluctuations and derivatives
- simplification in the dynamics of Goldstone boson π
- relations between physics and non-Gaussianities are clear!

General action

general action of quasi-single field inflation

relevant dof = three physical modes of graviton
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ex. $$S_{\rm mix} = \int d^4x \sqrt{-g} \left[\beta_1(t)\delta g^{00}\sigma + \beta_2(t)\delta g^{00}\partial^0\sigma + \beta_3(t)\partial^0\sigma - (\dot{\beta}_3(t) + 3H\beta_3(t))\sigma \right]$$

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Stuckelberg method

$$S_{\rm mix} = \int d^4x\, a^3\Big[-2\beta_1\dot\pi\sigma + (2\beta_2 - \beta_3)\dot\pi\dot\sigma + \beta_3\frac{\partial_i\pi\partial_i\sigma}{a^2} - \beta_1\Big(\dot\pi^2 - \frac{(\partial_i\pi)^2}{a^2}\Big)\sigma + 3\beta_2\dot\pi^2\dot\sigma - 2\beta_2\frac{\partial_i\pi\partial_i\sigma}{a^2}\dot\pi - \beta_2\frac{(\partial_i\pi)^2}{a^2}\dot\sigma + \dots\Big]$$

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large non-Gaussianitis from mixings β_1 and β_2

$\zeta \sim -H\pi$

Power spectrum

\# power spectrum

$$S_{\rm mix} = \int d^4x\, a^3 \left[\underbrace{-2\beta_1}_{\tilde\beta_1} \dot\pi\sigma + \underbrace{(2\beta_2 - \beta_3)}_{\tilde\beta_2} \dot\pi\dot\sigma + \underbrace{\beta_3}_{\tilde\beta_3} \frac{\partial_i\pi\partial_i\sigma}{a^2} \right]$$

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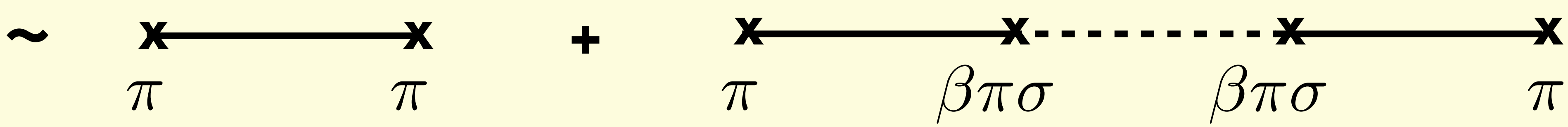

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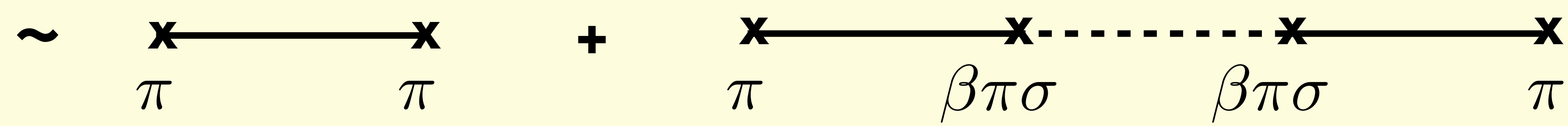


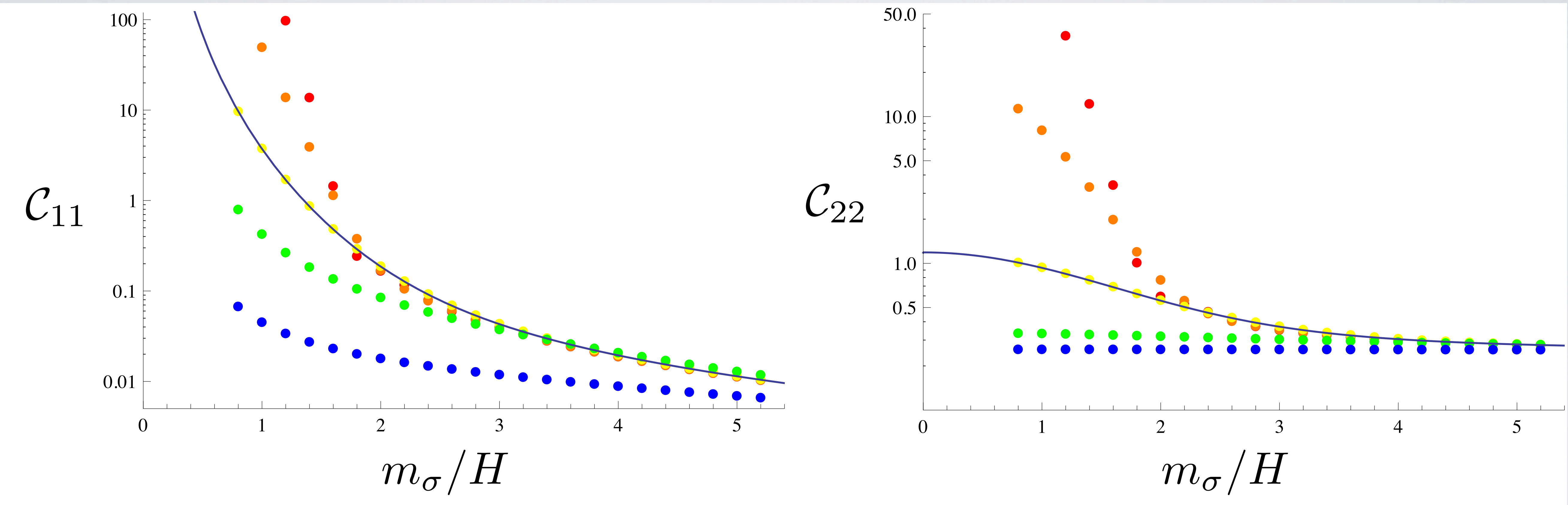
$$\langle \zeta_{\mathbf{k}}\, \zeta_{\mathbf{k}'} \rangle = (2\pi)^3 \delta^{(3)}(\mathbf{k} + \mathbf{k}') \frac{2\pi^2}{k^3} \mathcal{P}_\zeta(k)$$

deviation from single field

$$\mathcal{P}_\zeta(k) = \frac{H^2}{8\pi^2 M_{\rm Pl}^2 \epsilon\, c_\pi} \left[1 + \frac{\pi}{4\alpha_\sigma^2} \frac{c_\pi^2}{M_{\rm Pl}^2 (-\dot{H})} \left(\frac{\tilde{\beta}_1^2}{H^2} \mathcal{C}_{11} + \tilde{\beta}_2^2\, \mathcal{C}_{22} + \tilde{\beta}_3^2\, \mathcal{C}_{33} + \frac{\tilde{\beta}_1}{H} \tilde{\beta}_2\, \mathcal{C}_{12} + \frac{\tilde{\beta}_1}{H} \tilde{\beta}_3\, \mathcal{C}_{13} + \tilde{\beta}_2\, \tilde{\beta}_3\, \mathcal{C}_{23} \right) \right]$$

Power spectrum

$\mathcal{C}_{ij}(m_\sigma/H, c_\sigma/c_\pi)$ for fixed $r_s = c_\sigma/c_\pi$



The dots are numerical results for $r_s = 0.1$ (red), 0.3 (orange), 1 (yellow), 3 (green), and 10 (blue).

The curve is an analytic result for $r_s = 1$.

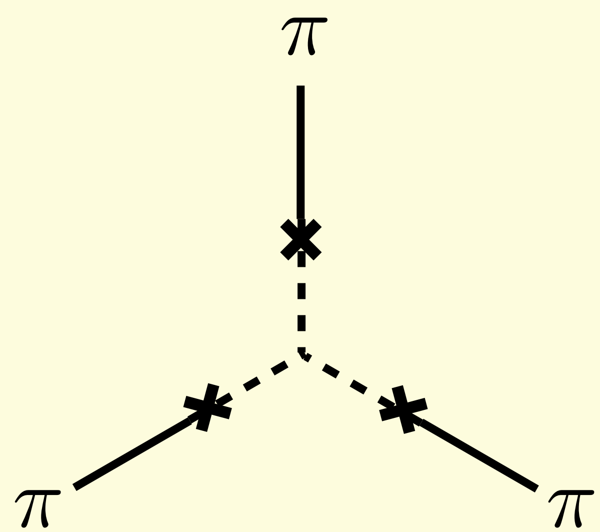
※ $\mathcal{C}_{22}$ does not vanish even in the heavy mass limit

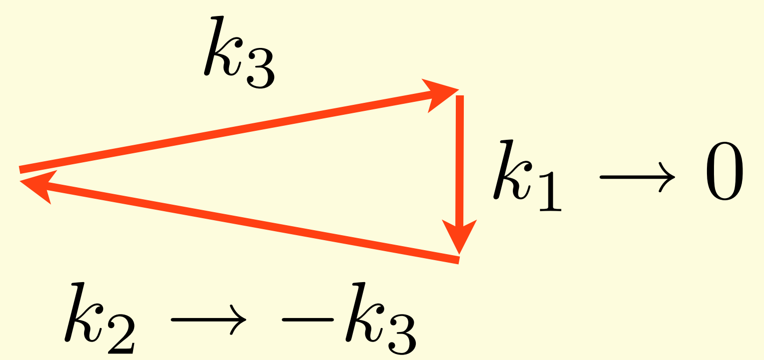
$\tilde{\beta}_2 \dot{\pi} \dot{\sigma}$

3pt functions

three point functions in the squeezed limit

- original models of quasi-single field inflation





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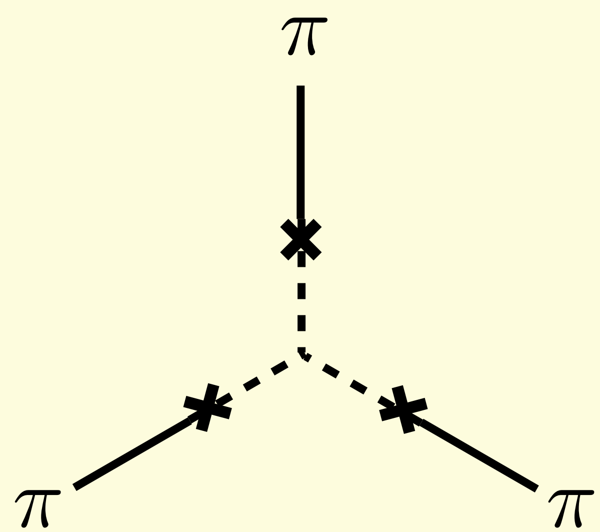

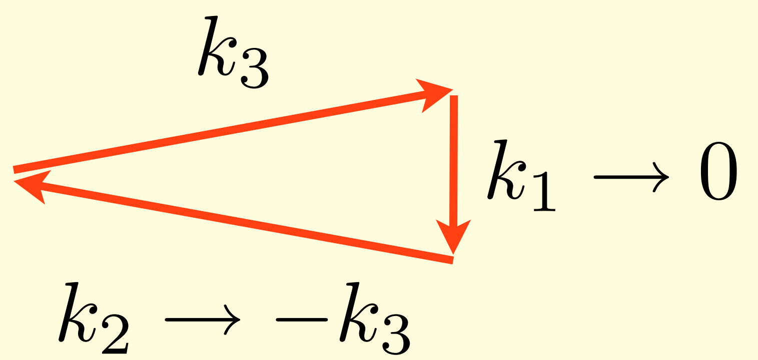

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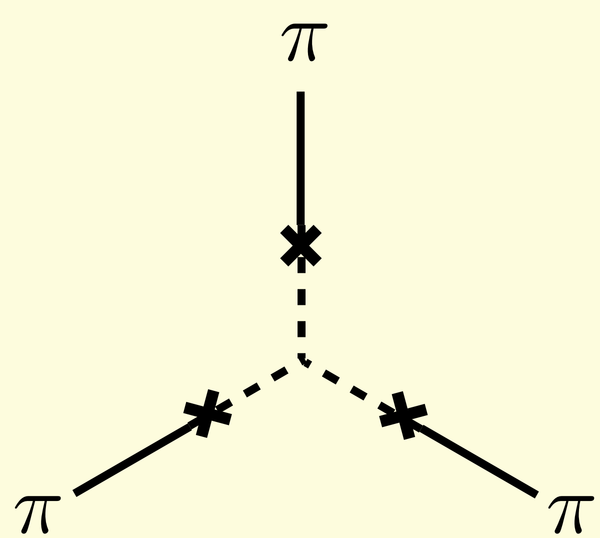

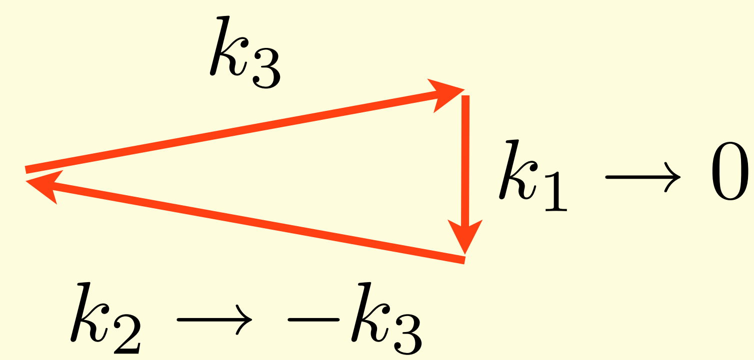

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① scaling does not depend on details of mixing

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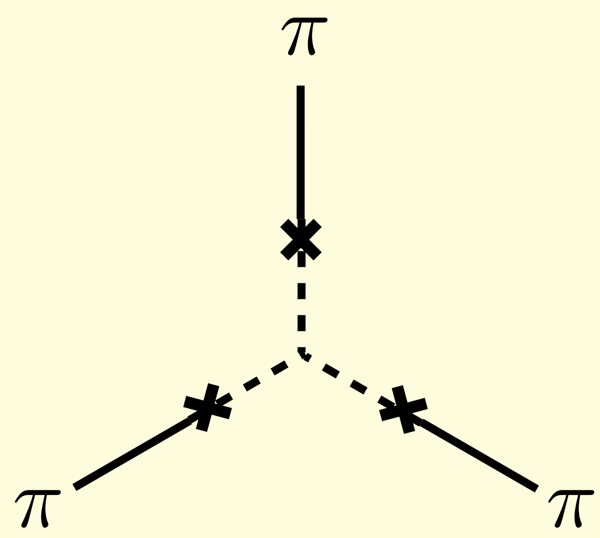

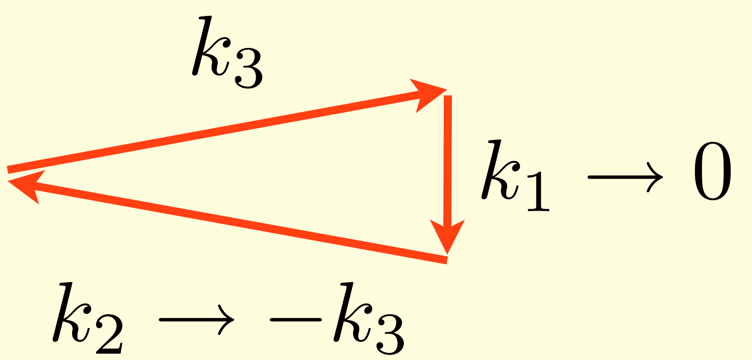

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② determined only from cubic interaction in the diagram

three point vertices	momentum dependence
$\dot{\pi}^3,\ \dot{\pi}\frac{(\partial_i\pi)^2}{a^2}$	$\kappa^{-1}k^{-6}$
$\dot{\pi}^2\sigma,\ \dot{\pi}\dot{\sigma},\ \dot{\pi}\sigma^2,\ \dot{\pi}\sigma\dot{\sigma},\ \dot{\pi}\dot{\sigma}^2,\ \ddot{\pi}\sigma\dot{\sigma},$ $\sigma^3,\ \sigma^2\dot{\sigma},\ \sigma\dot{\sigma}^2,\ \sigma\frac{(\partial_i\sigma)^2}{a^2},\ \dot{\sigma}^3,\ \dot{\sigma}\frac{(\partial_i\sigma)^2}{a^2}$	$\begin{cases}\kappa^{-3/2-\nu}k^{-6} & \text{for}\quad m_\sigma < \frac{3}{2}H \\ \kappa^{-3/2}k^{-6}\sin[i\nu\log\kappa+\delta_\nu] & \text{for}\quad m_\sigma > \frac{3}{2}H\end{cases}$
$\dot{\pi}\frac{\partial_i\pi\partial_i\sigma}{a^2}$	$\kappa^{-2}k^{-6}$
$\frac{(\partial_i\pi)^2}{a^2}\sigma,\ \frac{(\partial_i\pi)^2}{a^2}\dot{\sigma},\ \frac{\partial_i\pi\partial_i\sigma}{a^2}\sigma,\ \frac{\partial_i\pi\partial_i\sigma}{a^2}\dot{\sigma}$	$\begin{cases}\kappa^{-3/2-\nu}k^{-6} & \text{for}\quad m_\sigma < \sqrt{2}H \\ \kappa^{-2}k^{-6} & \text{for}\quad m_\sigma > \sqrt{2}H\end{cases}$
$\dot{\pi}\frac{(\partial_i\sigma)^2}{a^2}$	$\begin{cases}\kappa^{-1/2-\nu}k^{-6} & \text{for}\quad m_\sigma < \sqrt{2}H \\ \kappa^{-1}k^{-6} & \text{for}\quad m_\sigma > \sqrt{2}H\end{cases}$

non-trivial scaling in the squeezed limit when mixing is relevant!

$$\nu = \sqrt{9/4 - m_\sigma^2/H^2} \qquad 0 < \nu < 3/2 \quad \text{or} \quad \nu = \text{pure imaginary}$$

Summary and prospects

\# summary

applied EFT approach to QSI

- systematic expansions in fluctuations and derivatives
- simplification of action for π in decoupling regime
- relation between physics & non-Gaussianities is clear

calculated power spectrum for constant mixing

discussed scaling of 3-pt functions in squeezed limit

- sensitive to # of fields and their mass

also discussed effects of heavy particles, sharp turning

\# prospects

full non-Gaussianities, detectability, ...

EFT for sugra based inflation,

more on sharp turning, ...

THANK YOU!!