# Correcting scalar propagators in de Sitter

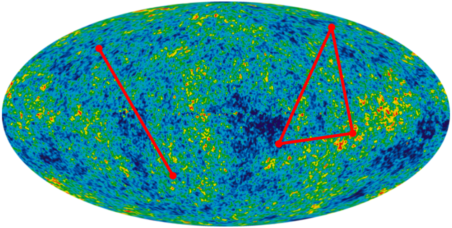
Mang Hei Gordon Lee

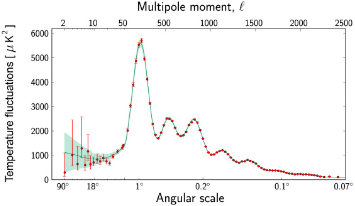
LeCosPa, NTU

Based on upcoming work with Scott Melville

# Correlators

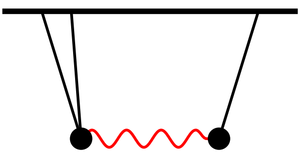
- Scalar curvature perturbations are linearly related to fluctuations in CMB.
- Measured power spectrum (two point)
- Hope to measure primordial non-Gaussianities in higher point correlations.

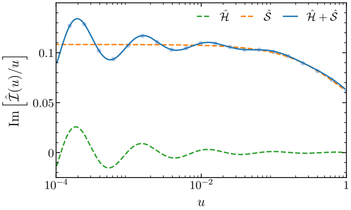




# Why higher point?

- The interesting physics of inflation lies here: interactions produces non-Gaussianities.
- Massive particles decay during inflation, cannot detect directly.
- Can see them through interactions.
- Different features in the measured correlators (e.g. massive fields give oscillatory signals).






Credit to Dong Gang Wang.

# A story from particle physics

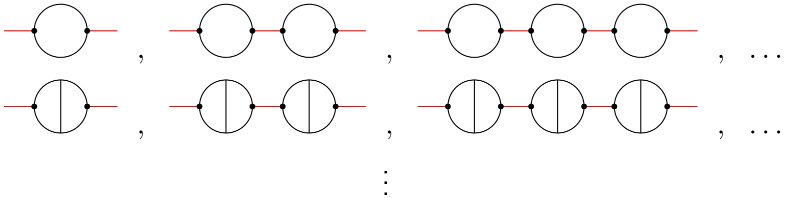
- Important to understand how measurements relate to theory.
- Suppose some random theorist hands you this:

$$S = \int d^d x \left[ \frac{1}{2}(\partial\phi)^2 - \frac{1}{2}m^2\phi^2 - \frac{\lambda}{3!}\phi^3 \right]$$

- You measure the mass of the particle. Does that give you $m^2$?

# A story from particle physics

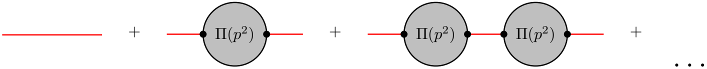
- No. The mass receives corrections from self interactions.



- Corrections are generally divergent: need to renormalize by adding counterterms which cancel the divergences.

# A story from particle physics

- These contribution can be resummed as a geometric series.




$$
= \frac{1}{p^2 - m^2} + \frac{1}{p^2 - m^2} \sum_n \left( \frac{\Pi(p^2)}{p^2 - m^2} \right)^n
$$

$$
= \frac{1}{p^2 - m^2 - \Pi(p^2)} = \frac{1}{\Gamma(p^2)}
$$

- The mass you are measuring is in fact $\Gamma(0)$ (after renormalization).
- Generically this depends on both $m^2$ and $\lambda$.

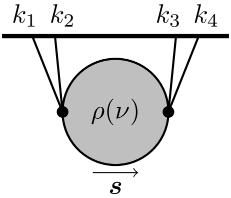
# So let's do it for de Sitter!

- Expressions for correlators in de Sitter are generally more complicated.
- Some theories are easier than others (conformal/massless scalars).
- Example: tree level exchange in flat space vs dS (for particle with mass $\mu^2$)

| Flat space | de Sitter |
|---|---|
| $\frac{1}{p^2 - m^2}$ | $\frac{\pi P_{i\mu-\frac{1}{2}}(\frac{1}{u}) P_{i\mu-\frac{1}{2}}(-\frac{1}{v})}{2\cosh(\pi\mu)} + \sum_{m,n} c_{m,n}(\mu) u^{1+2m} \left(\frac{u}{v}\right)^n$ |

- Point: clear difference in simplicity.

# Spectral representation

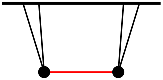
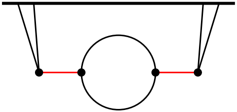
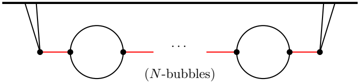



- Any exchange diagram can be represented in this form:

$$I_4 = \int_{-\infty}^{\infty} d\nu \, \mathcal{N}_\nu \, \rho(\nu) \, V_1\left(\frac{k_1+k_2}{s}, \nu\right) V_1\left(\frac{k_3+k_4}{s}, \nu\right).$$

- Importantly, $V_1$ is completely fixed by symmetry and does not depend on the diagram.
- Only $\rho(\nu)$ encodes the interaction, so we work at the level of $\rho(\nu)$.

# Everything simplifies

| Graph | $\rho(\nu)$ |
| --- | --- |
|  | $\frac{1}{(\nu^2-\mu^2)_{i\epsilon}}$ |
|  | $\rho^{1L} = \sum_n \frac{a(n,\mu)}{\nu^2-(i\frac{d}{2}+2in\pm\mu\pm\mu)^2}$ |
|   | $\rho^{NL} = \frac{(\rho^{1L})^N}{(\nu^2-\mu^2)_{i\epsilon}^{N+1}}$ |

# Resummation

- Now you can renormalize and resum the answer just like in flat space:

$$\sum_N \rho^{NL} = \frac{1}{(\nu^2 - \mu_R^2 - \rho^{1L})_{i\epsilon}} = \frac{1}{\Gamma(\nu^2)}$$

- Just like flat space, the physical mass you measure is $\Gamma(0)$, and it depends on the $\mu^2$ and $\lambda$.
- Crucial property that allows this to happen: $\nu^2$, similar to the center of mass energy in scattering amplitudes, is conserved.

# What's next?

- $\rho(\nu^2)$ for theories without full dS isometry.
  - Simple examples in tree level seems to indicate this still works (with some modifications).
- Spinning fields?
  - What is the analogue of $t$ channel?
  - Crossing?
  - Dynamical corrections to the coupling constants.
- Positivity bounds?
  - How does physical principles constraint $\rho(\nu^2)$?