FUNDAMENTAL LIMITS ON CONSTRAINING PRIMORDIAL NON-GAUSSIANITY

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[arxiv: 2011.09461](https://arxiv.org/abs/2011.09461)

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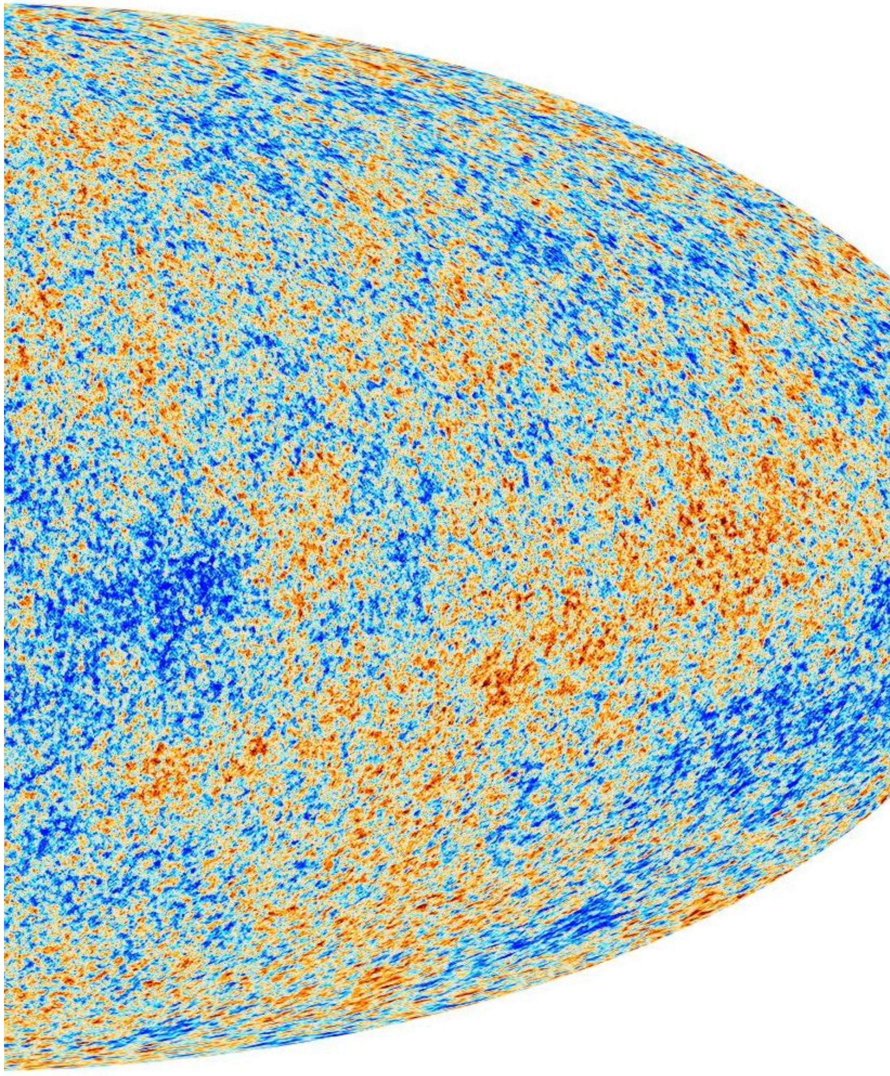
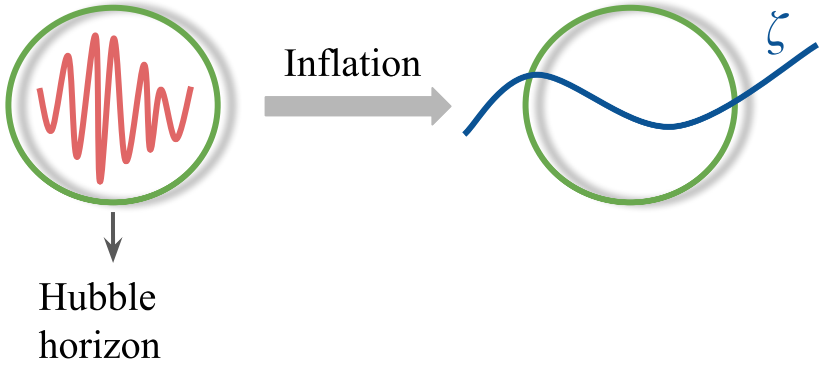


OUTLINE

Question: how are constraints on primordial non-Gaussianity going to improve with resolution?

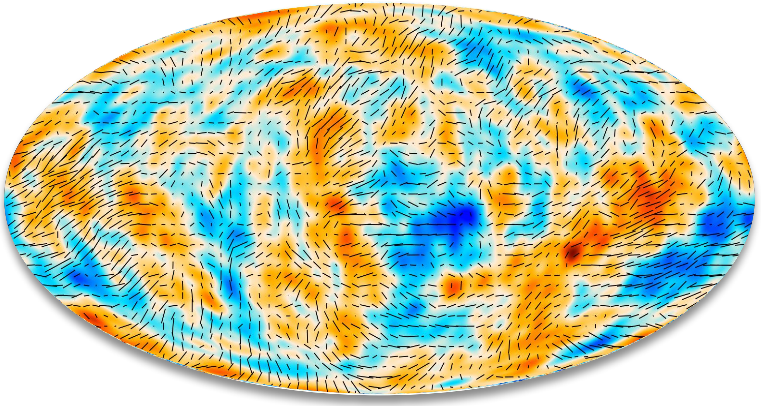
- ➔ Introduction and motivation: statistics of primordial fluctuations and non-Gaussianity.
- ➔ How do we count information? Fundamental limits of tracers: cosmic microwave background (CMB).
- ➔ Analytical and numerical results: kinematical limits of cosmological correlators.

COSMIC INFLATION



Quantum fluctuations during inflation are stretched to cosmic distances.

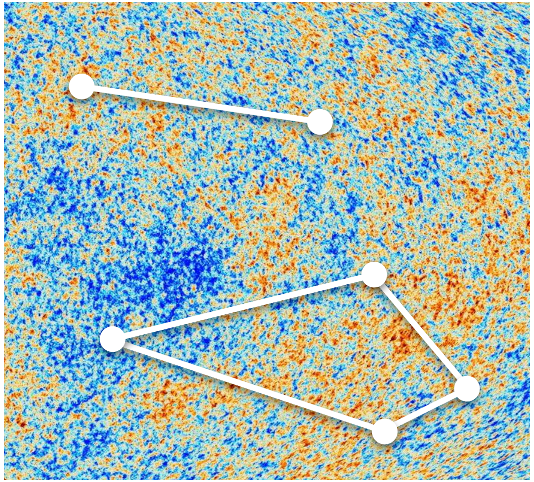
Primordial fluctuations are imprinted in the Cosmic Microwave Background (CMB) anisotropies.



ESA, Planck Collaboration

COSMOLOGICAL CORRELATORS

The spatial correlations between cosmological structures contain a wealth of information about the physics of the early universe.



Gaussian distributed fluctuations:

➔ 2-pt correlation function (power spectrum)

$$\langle TT \rangle \propto [\text{transfer function}] \times \langle \zeta\zeta \rangle$$

➔ Planck result 2018: nearly scale-invariant, adiabatic and **nearly Gaussian** fluctuations.

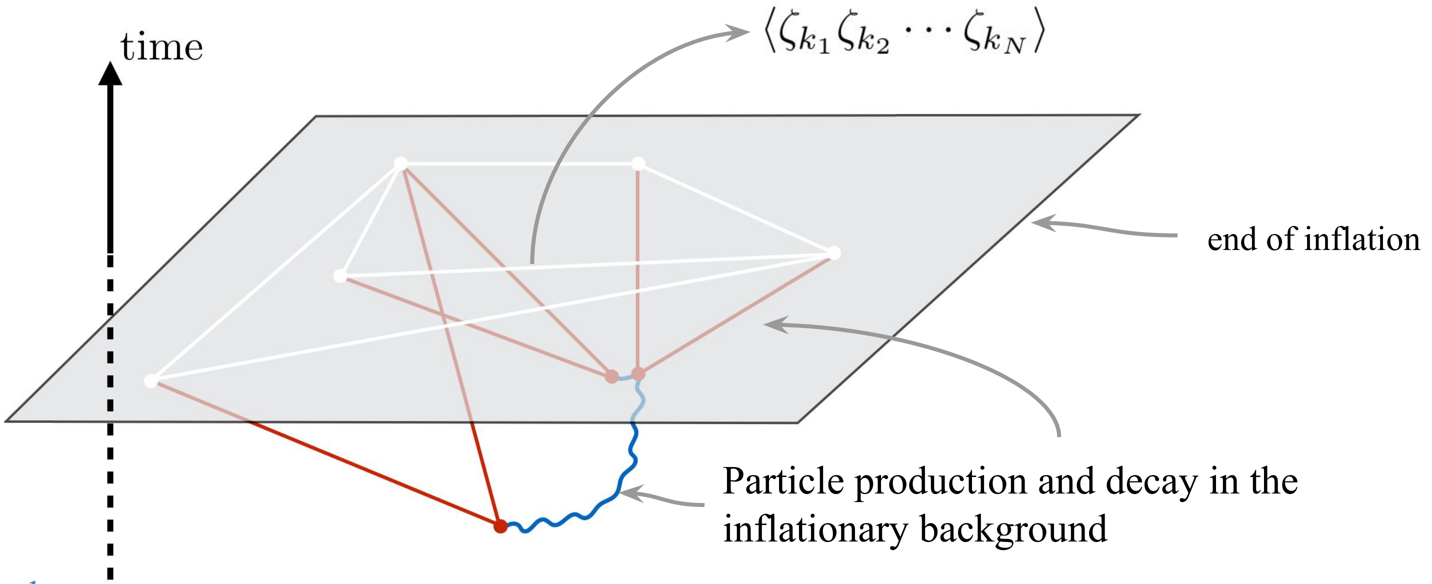
1807.06209

What is the physics of inflation?

$$\langle TTT \cdots T \rangle \neq 0$$

PRIMORDIAL NON-GAUSSIANITY

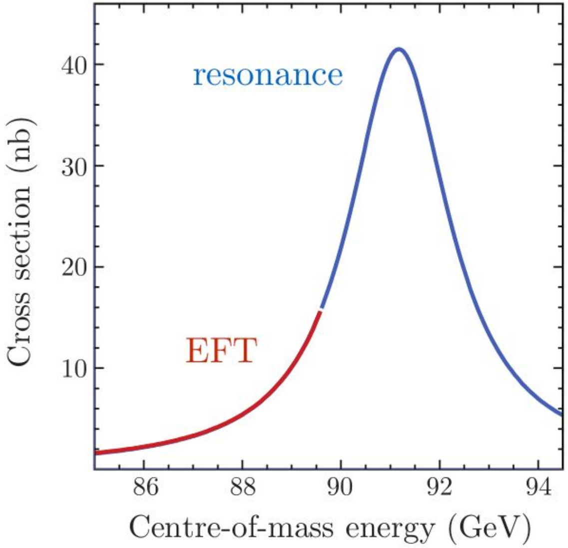
Inflationary models predict deviations from Gaussianity: different physical processes during inflation give rise to distinctive **signatures of non-Gaussianity**.

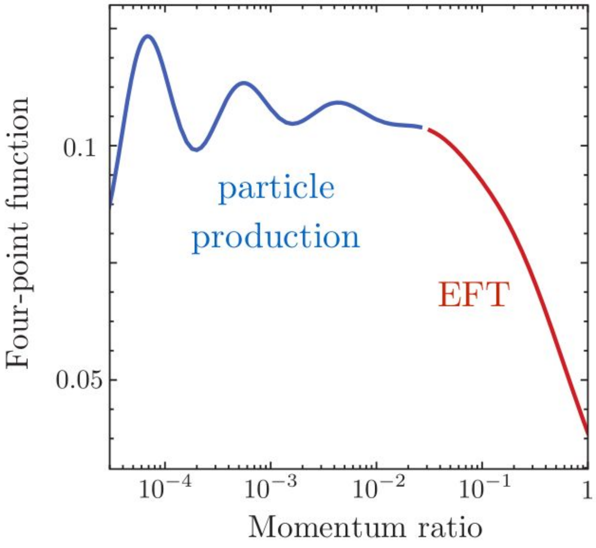


Credits: Gui Pimentel

COSMOLOGICAL COLLIDER PHYSICS

Correlators encode information about the **mass** (and spin) of particles mediating the interactions among the curvature fluctuations. Just like in collider physics!





[1503.08043](), [1607.03735]()

Credits: Daniel Baumann

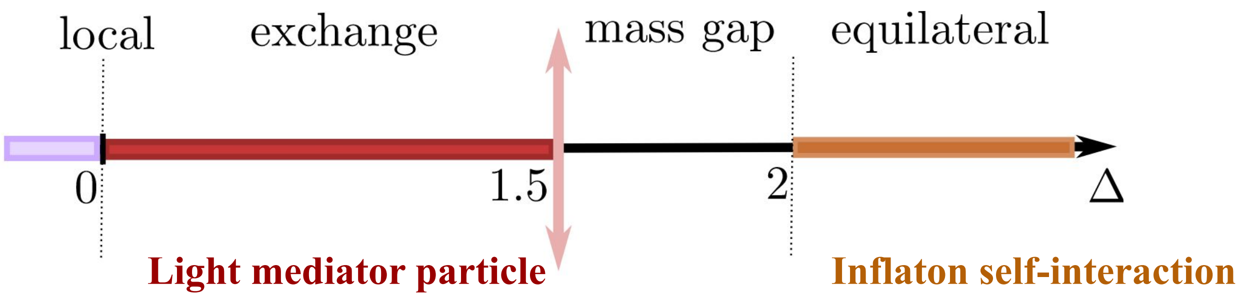
COSMOLOGICAL COLLIDER PHYSICS

➔ **Squeezed limit:** coupling between perturbations generated at different times.

$$\langle \zeta_{k_1} \zeta_{k_2} \cdots \zeta_{k_N} \rangle \propto \left(\frac{k_{\rm long}}{k_{\rm short}} \right)^{\boxed{\Delta}}$$

➔ **Collapsed limit:** perturbations sourced at similar times mediated by an early-produced particle.

$$\Delta = 3/2 - \sqrt{9/4 - \boxed{m_\sigma^2}/H^2}$$



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IN OTHER WORDS...

Correlation functions beyond the power spectrum contain a wealth of information about the physics of the early universe:

- Discriminate between and/or rule out inflationary models.

Future experiment will increase in resolution and sensitivity: **how do we expect future constraints on non-Gaussianity to improve?**

MODE COUNTING

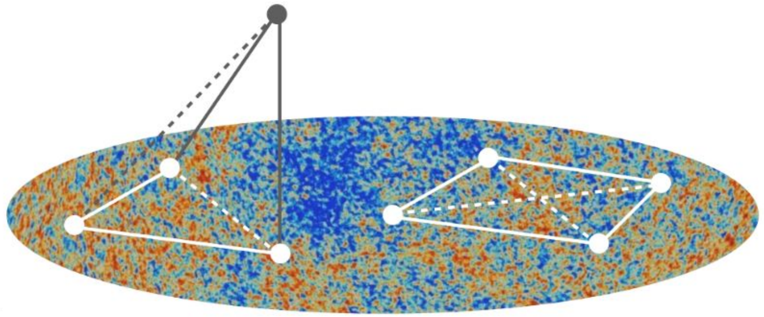
Ideal experiment: no noise, no foreground, only cosmic variance.

- N number of independent samples, then the error on the measurement decreases as $\sqrt{N}$.
- For a CMB experiment, N is the number of pixels (spherical harmonics)

$$\sigma^{-2} = \left(\frac{\text{Signal}}{\text{Noise}}\right)^2 \propto \ell_{\text{max}}^2$$

- Similarly, for a 3D experiment

$$\sigma^{-2} = \left(\frac{\text{Signal}}{\text{Noise}}\right)^2 \propto k_{\text{max}}^3$$



Projection effect.

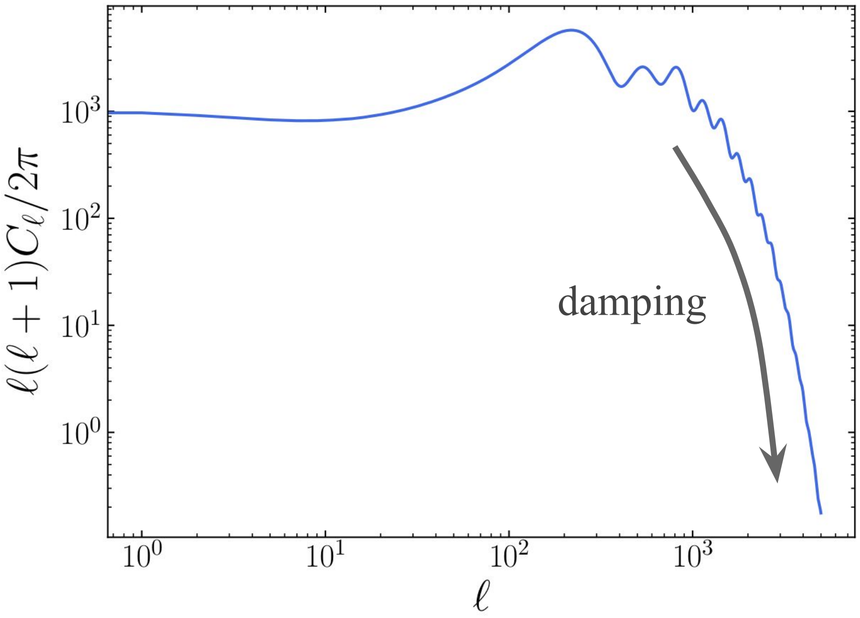
FUNDAMENTAL LIMITS: DIFFUSION DAMPING

At small scales perturbations are washed out by photons travelling from hot regions of space to cold ones (**diffusion/Silk damping**).

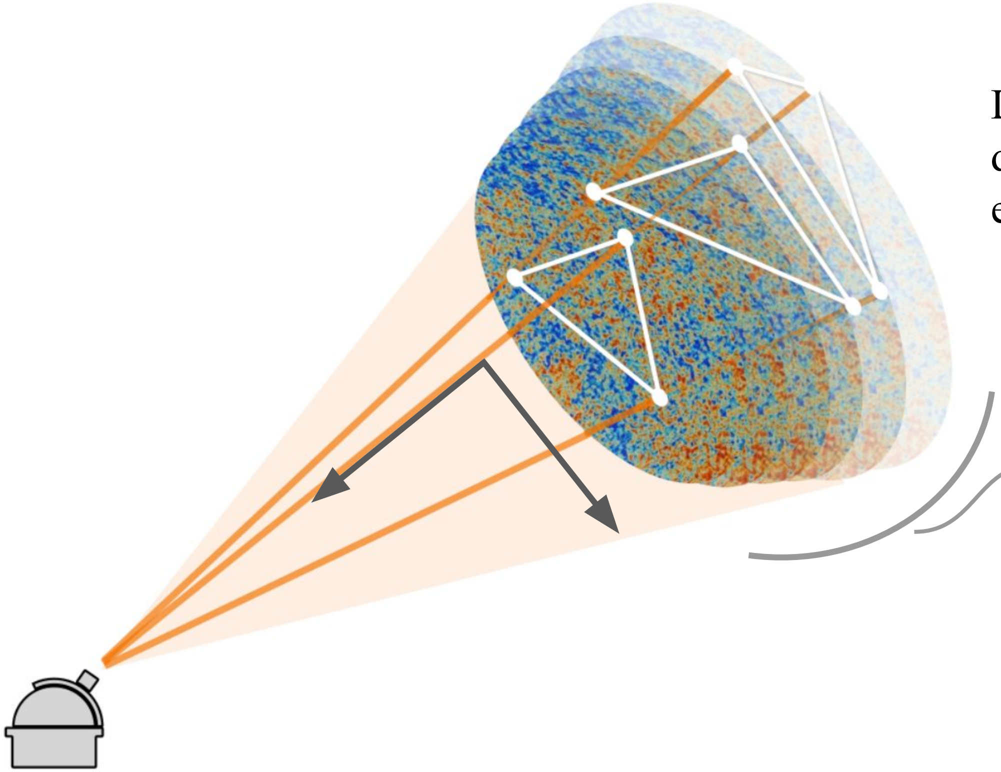
$$\sigma^{-2} = \left(\frac{\text{Signal}}{\text{Noise}}\right)^2 \propto \ell_{\max}^{N-4}$$

Intrinsic and fundamental limitation!

Bispectrum: $(S/N)^2 \propto \ell_{\max}$



“BLURRING” EFFECT



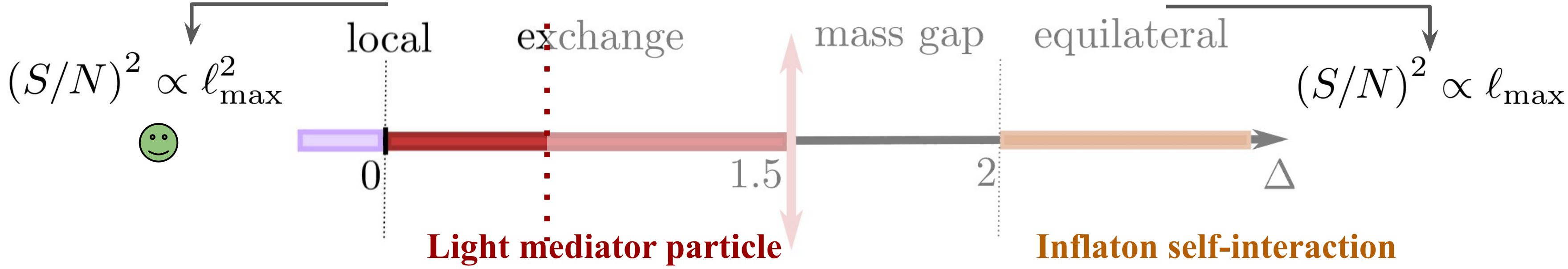
Loss of information at small scales due to diffusion damping. But signal and noise are equally damped!

The last scattering surface has a finite **thickness**: average over all possible triangles along the same line of sight.

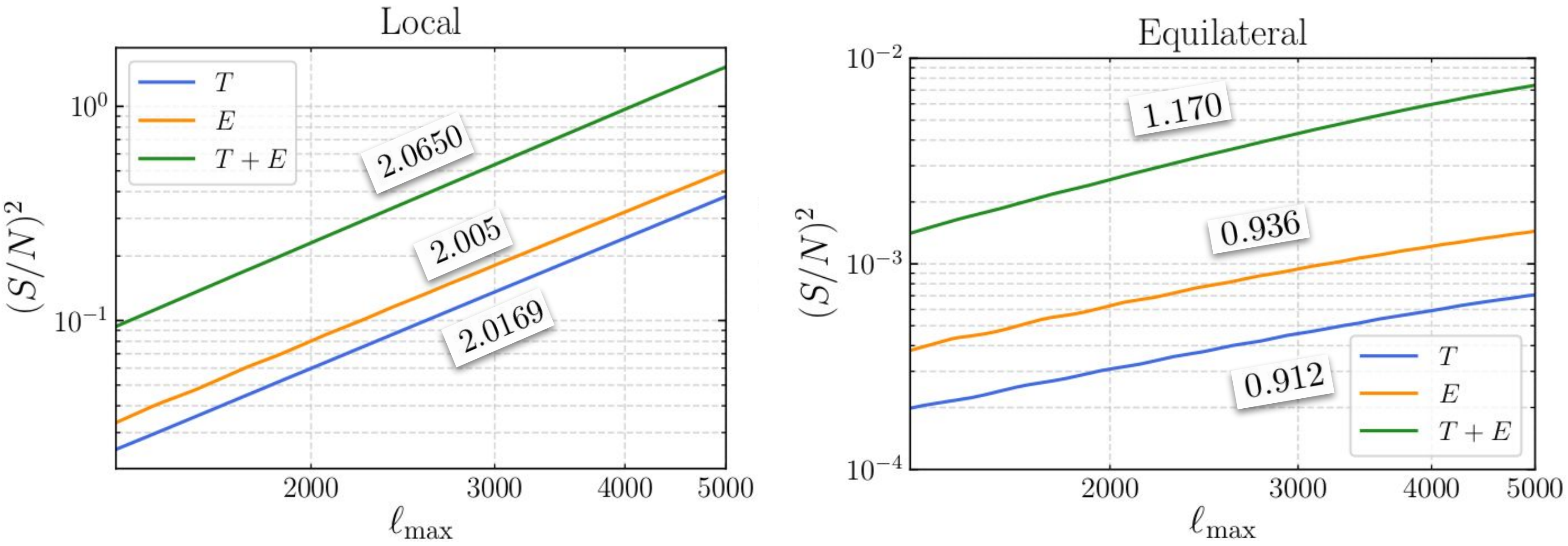
➔ ***Blurring*** of the measurement: reduced *S/N*, increased variance.

ANALYTICAL RESULTS: SQUEEZED LIMIT

We find the leading *S/N* scaling with the resolution for all N-point correlation functions $\langle TTT \cdots T \rangle$ in the squeezed limit.



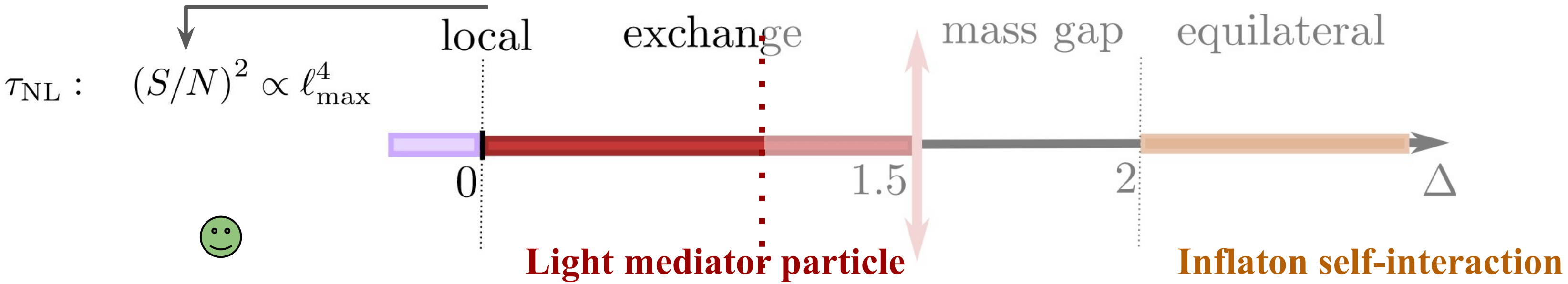
NUMERICAL RESULTS: BISPECTRUM



- ➔ Local and equilateral agree with analytical solutions.
- ➔ *E*-mode polarization is affected by damping, but *T*+*E* improves poor scaling.

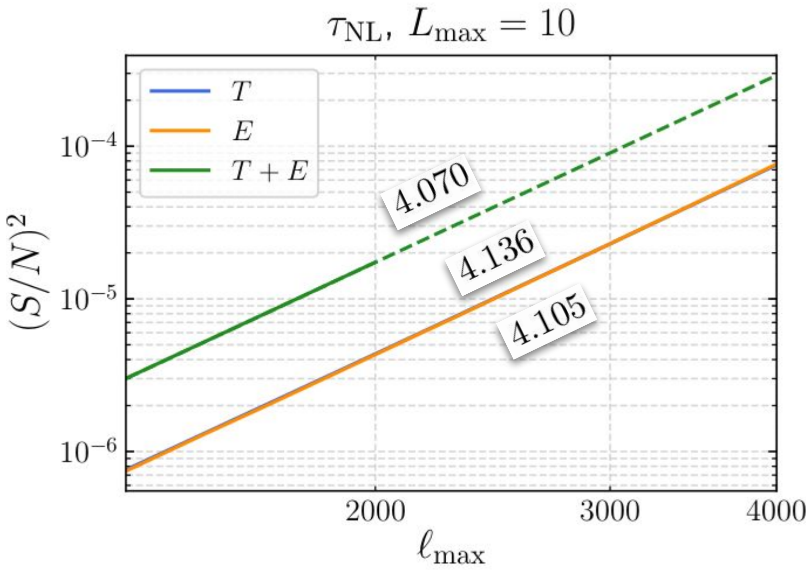
ANALYTICAL RESULTS: COLLAPSED LIMIT

We find the leading *S/N* scaling with the resolution for all N-point correlation functions $\langle TTT \cdots T \rangle$ in the collapsed limit.



The trispectrum scales better than the bispectrum!

NUMERICAL RESULTS: TRISPECTRUM

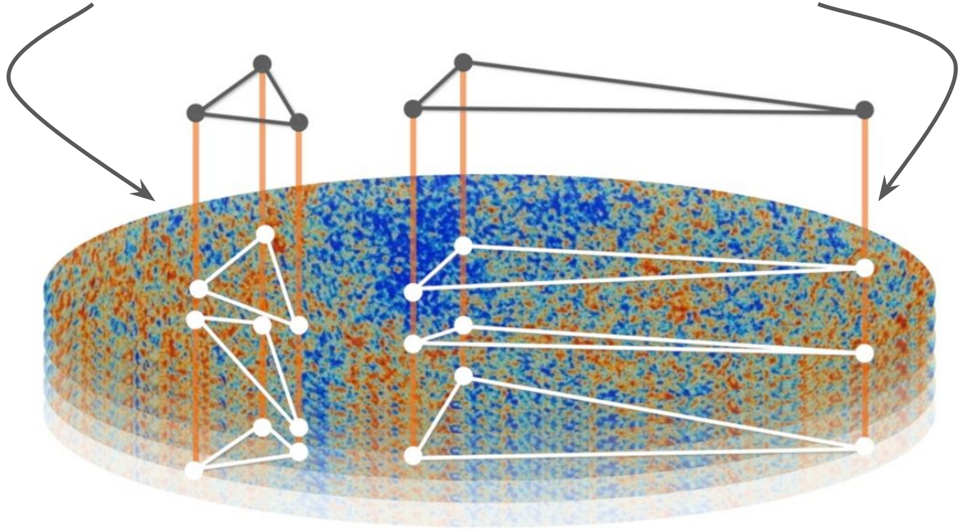


➔ Agrees with analytical solution.

➔ Scaling is already optimal, *T*+*E* doesn't improve significantly.

SHAPE MATTERS

Constraints depend on the shape of the correlators:
equilateral shapes are more affected than **squeezed** ones.



➔ Equilateral shapes have a reduced *S/N*.

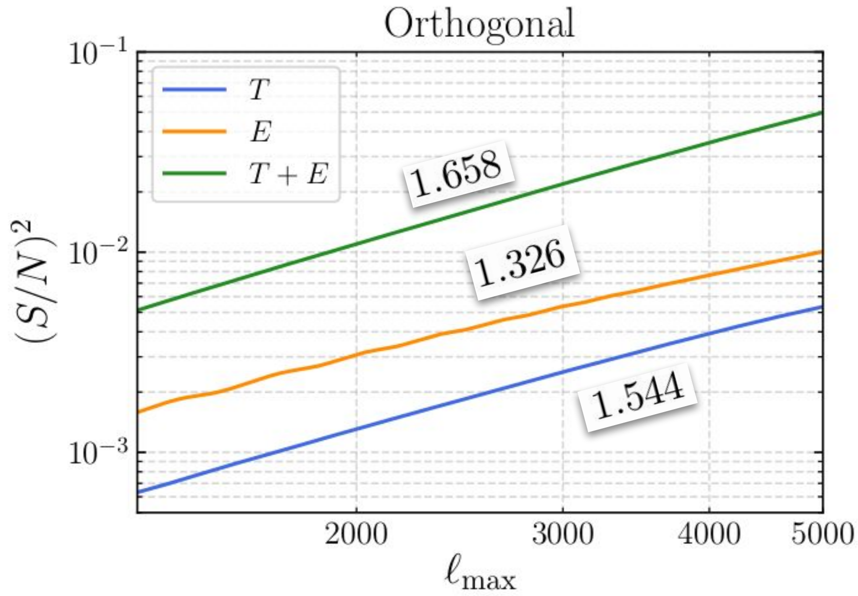
CONCLUSIONS

- ➔ The *S/N* scaling is reduced due to blurring of the last scattering surface at small scales, but in certain kinematical limits, higher order correlation functions still provide a wealth of information about the early universe physics.
- ➔ Equilateral shapes are more affected than squeezed shapes.
- ➔ Fisher forecasts suggest that analytical estimates capture the scaling for the bispectrum and trispectrum at small scales.
- ➔ Adding polarization data improves the scaling of spectra that are not already close to mode-counting.

Thank you and see you at the live discussion!

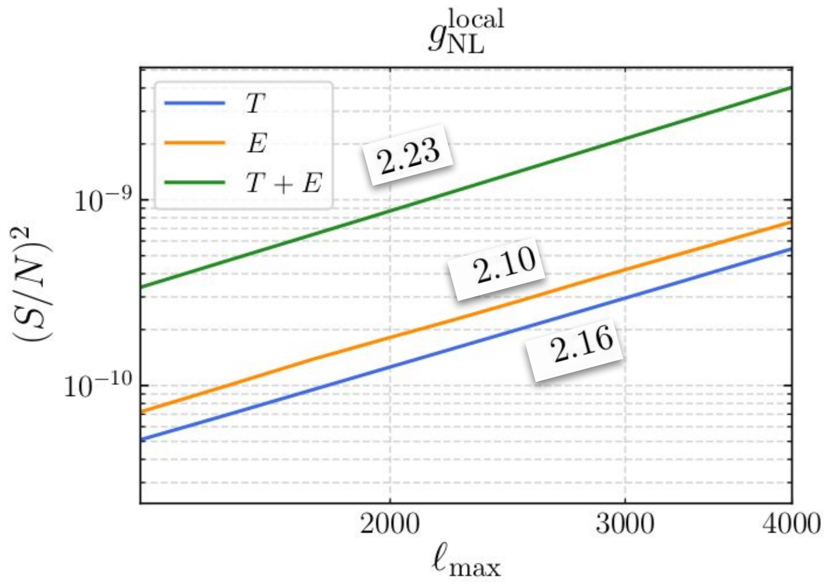
APPENDIX

NUMERICAL RESULTS: ORTHOGONAL BISPECTRUM



➔ Orthogonal presents a better scaling: analytical treatment doesn't capture the full scaling, the shape slowly converges to the leading scaling; effect of the folded limit.

NUMERICAL RESULTS: NESTED SQUEEZED



g_{NL} : $\quad (S/N)^2 \propto \ell_{\max}^2$ $\quad$ (double squeezed)

➔ Agrees with theory, *T*+*E* gives an improvement.