Hidden in the background: A local approach to CMB anomalies

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Based on:

- JBS, Phys. Lett. B 739 (2014) 269-278
- plus some other work
  - in preparation (for too long now)
  - in progress
  - in store

The robust and healthy inflationary paradigm

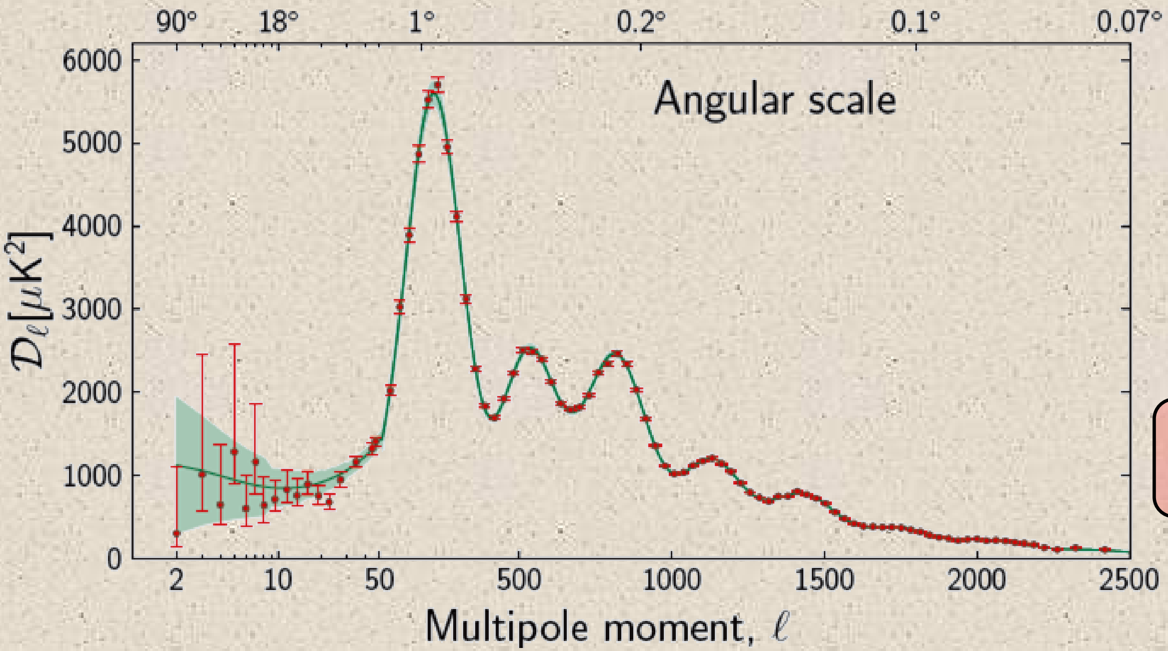
Inflation is a successful **paradigm** addressing difficulties of the Big Bang

Flatness , horizon, initial density perturbations, unwanted relics…

Not being a theory, inflation is much like Pandora's box:

Too large a number of inflationary models

Observations (COBE, WMAP, PLANCK) to discriminate models



Planck '13 (I, XV, XVI)

7 acoustic peaks

No firm evidence for physics beyond 6-parameter ΛCDM

Great bittersweet success!

+ anomalies

The CMB anomalies

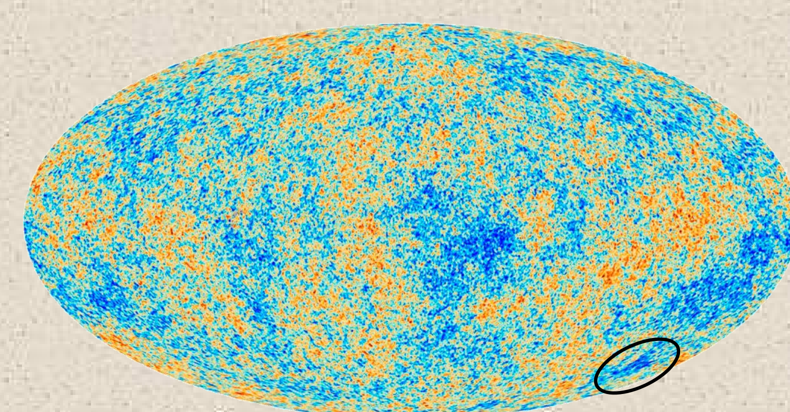
Planck confirms the anomalies seen by WMAP

1. *Mode alignment*
2. *Variance, skewness, and kurtosis anomalies*
3. *Hemispherical Asymmetry*
4. *Phase correlations*
5. *Power asymmetry*
6. *Dipole modulation*
7. *Generalized modulation*
8. *Parity asymmetry*
9. *The Cold Spot*

$$\frac{\delta T}{T}(\hat{n}) = s(\hat{n})\left[1 + A(\hat{n}.\hat{p})\right]$$

$A = 0.072 \pm 0.022$

direction $(l, b) = (224, -22) \pm 24$



A framework to break the homogeneity of the CMB

The question

How much do you need to twist the inflationary paradigm to obtain anomalies?

(i.e. breaking homogeneity & isotropy of the CMB)

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Inflaton responsible for most of the CMB perturbations (homogeneous & isotropic)

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The outcome

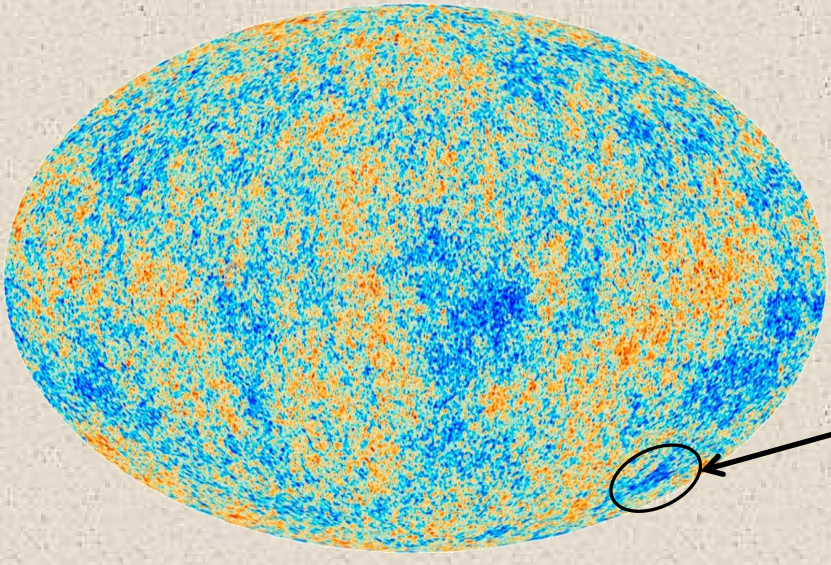
Inhomogeneous distribution of the field at the end of inflation

Breaking of statistical homogeneity of the CMB

Avenue towards CMB anomalies

Warm up: The Cold Spot

Only significant deviation from Gaussianity
- (WMAP 1: Vielva et al. '04)
- (WMAP 3: Cruz et al. '07)
- (Planck '13 XXIII)
- 2.35σ effect



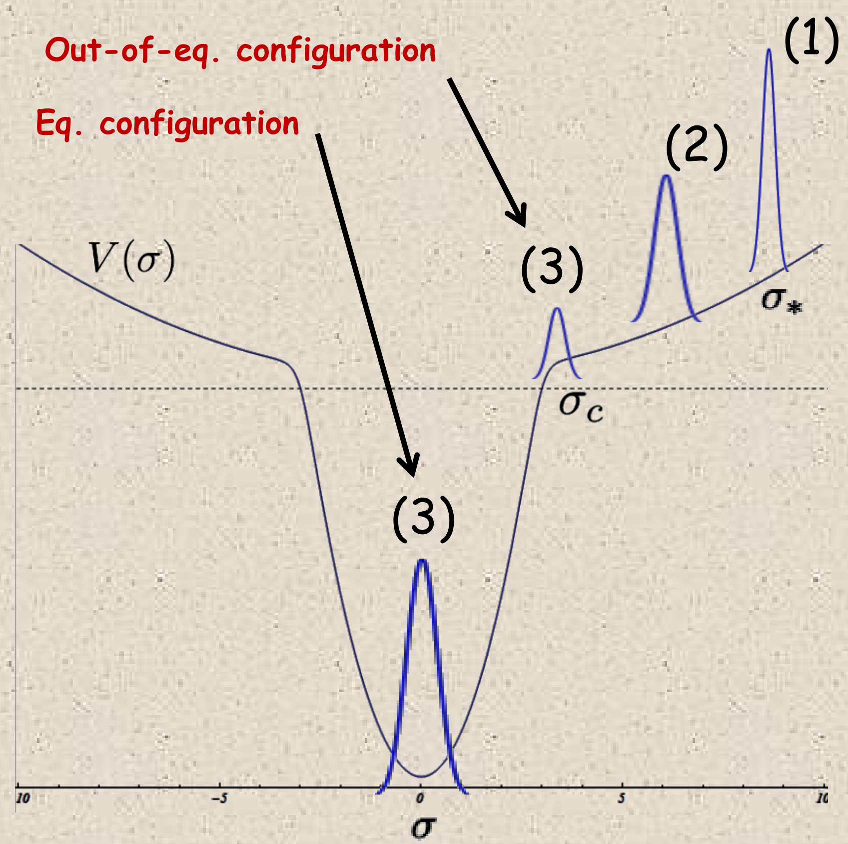
(ESA Planck collaboration)

- $b = -57^\circ\,,\, l = 209^\circ$
- Angular size $\sim 10^\circ$
- $\Delta T \simeq -78\,\mu K$
- $P_{\rm Gauss.} \approx 0.2\%$

Warm up: The Cold Spot

Initially excited, massive, interacting σ

$$g^2\sigma_*^2 \gg H^2 \longrightarrow \sigma_c \sim g^{-1}H$$



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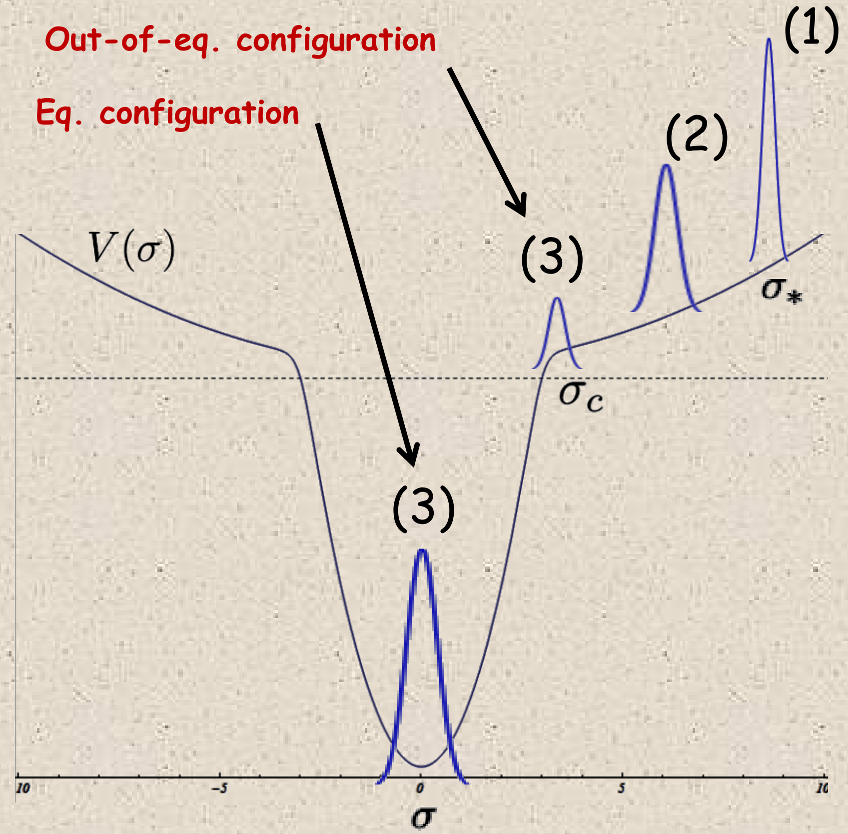
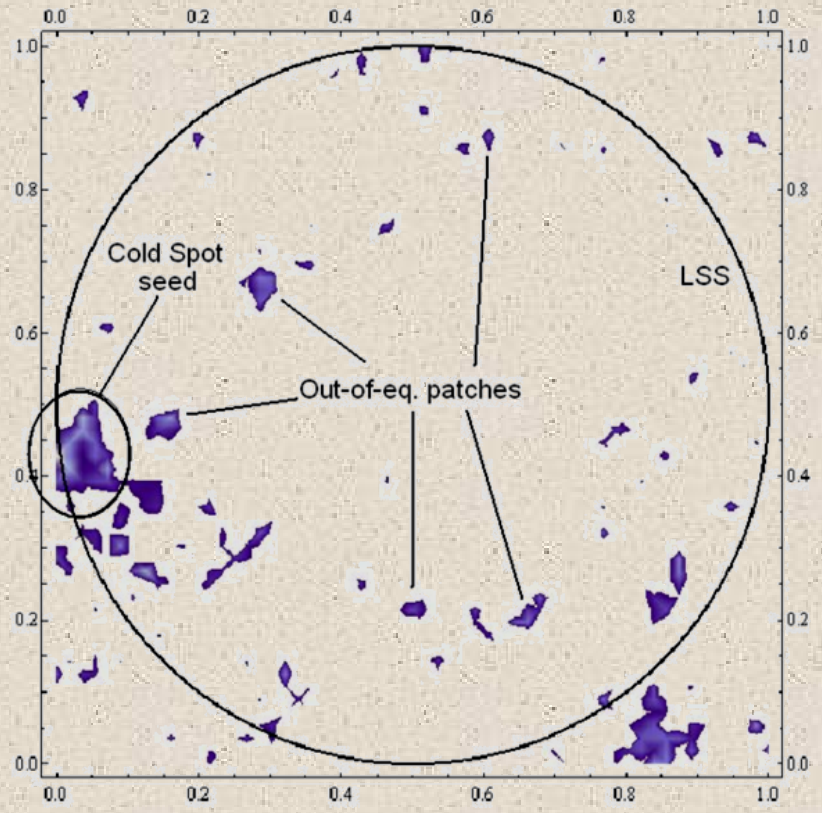


Spatial profile

Emergence of a patchy structure



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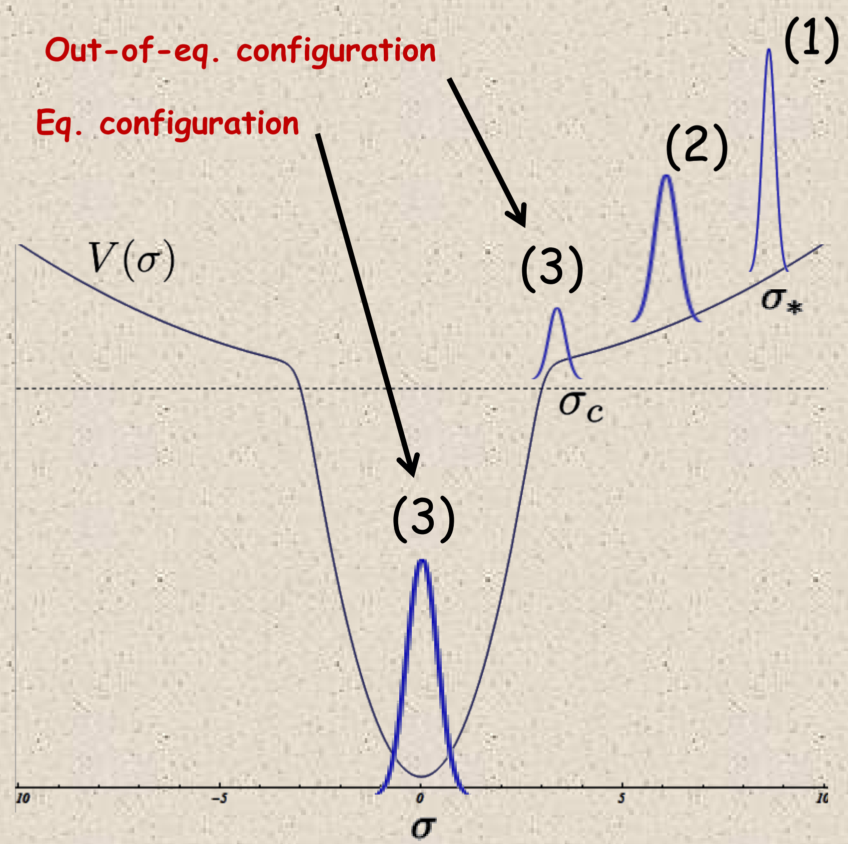

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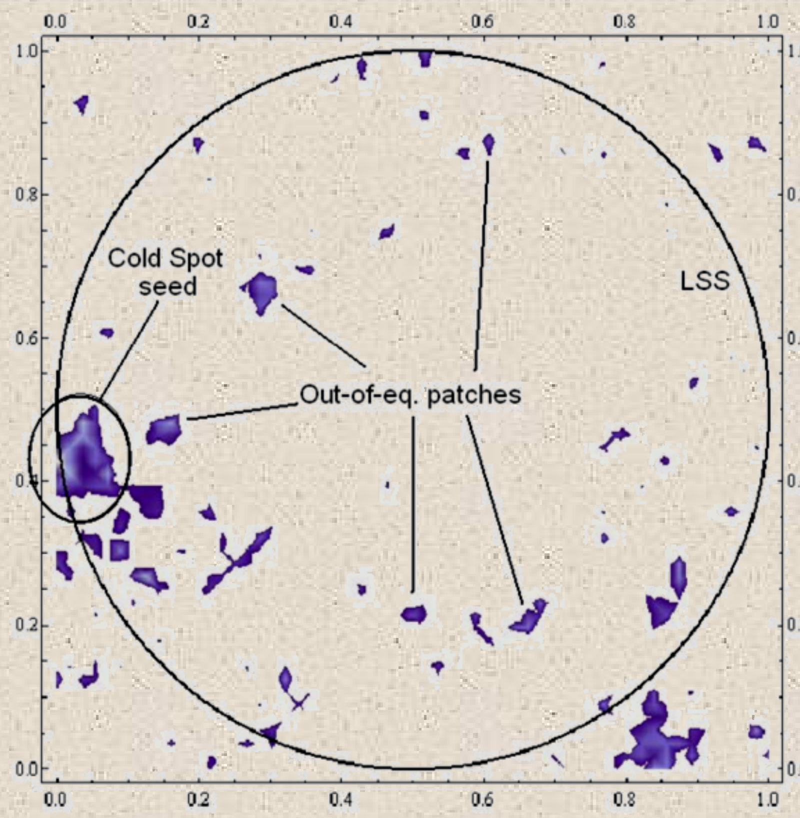


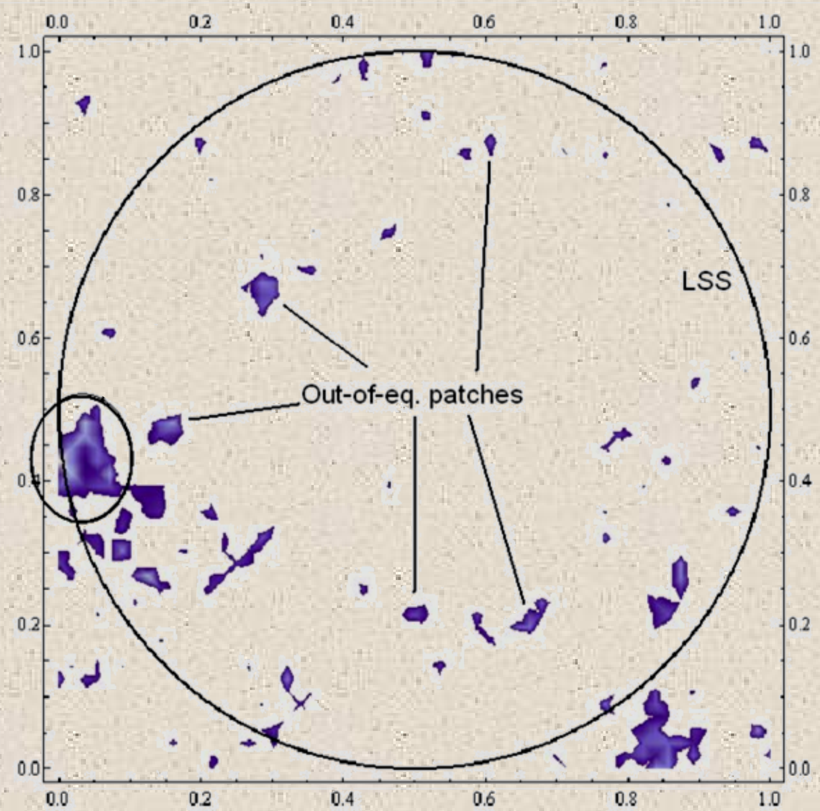
JBS, Phys. Lett. B 739 (2014) 269-278 + in preparation (full-blown details)

(σ modulates inflaton's decay: Localized inhomogeneous reheating)

Breaking the isotropy of the CMB

Contribution of vector fields to the CMB is strongly constrained

$$\mathcal{P}_\zeta(\mathbf{k}) = \mathcal{P}_\zeta^{\rm iso}(k)\left(1 + g(\hat{\mathbf{d}}\cdot\hat{\mathbf{k}})^2\right) \qquad g \lesssim 0.02$$, Kim & Komatsu, 2013



Can we generate a **Local** direction-dependent contribution to the CMB?

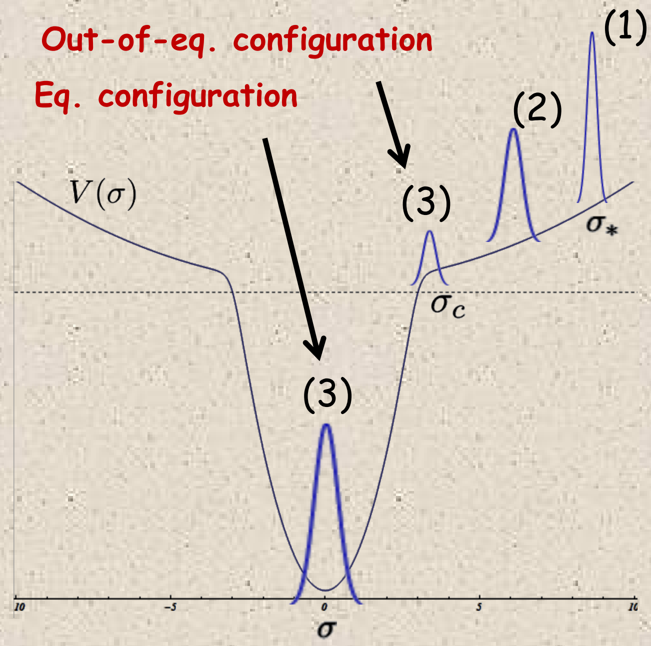
Breaking the isotropy of the CMB

A simple example known to be ***free of instabilities*** is

$$\mathcal{L} = -\frac{1}{4} f(\sigma) F_{\mu\nu} F^{\mu\nu} + \frac{1}{2} m_A^2 A_\mu A^\mu$$

Vector curvaton mechanism to contribute to the CMB

$$\zeta \propto \rho_{A,\mathrm{end}}^{1/2}$$



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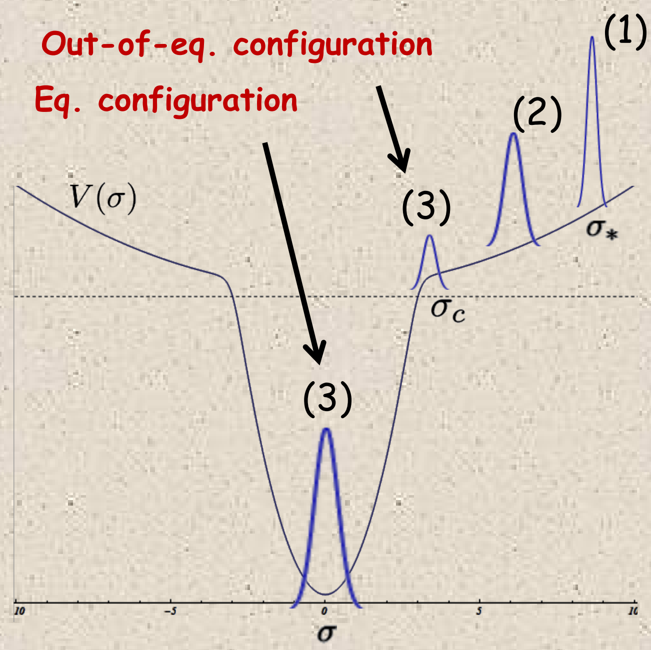
Out-of-eq. configuration

Using $f(\sigma) \propto a^\alpha$ ⟶ Scale invariance for α = -4

Scaling continues until the end of inflation



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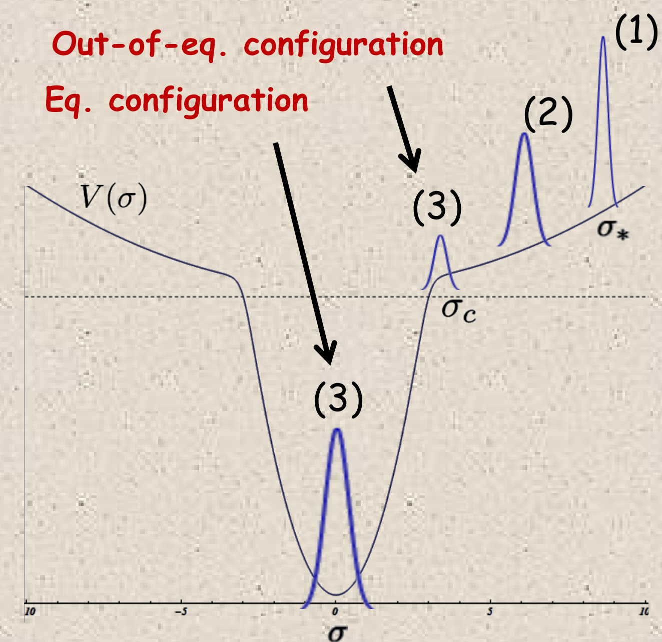

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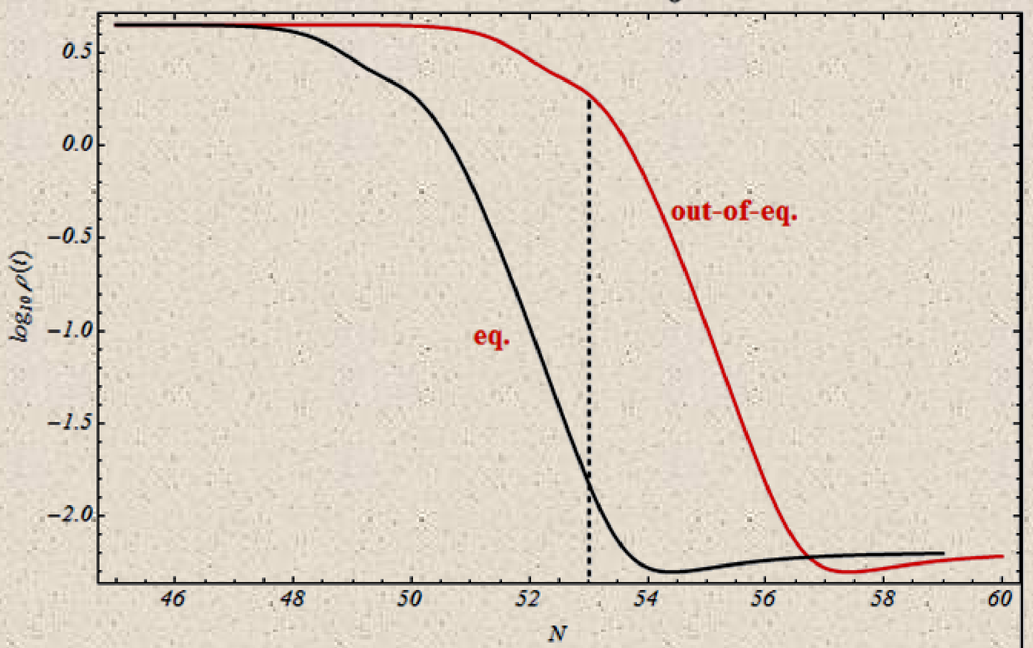
eq. configuration

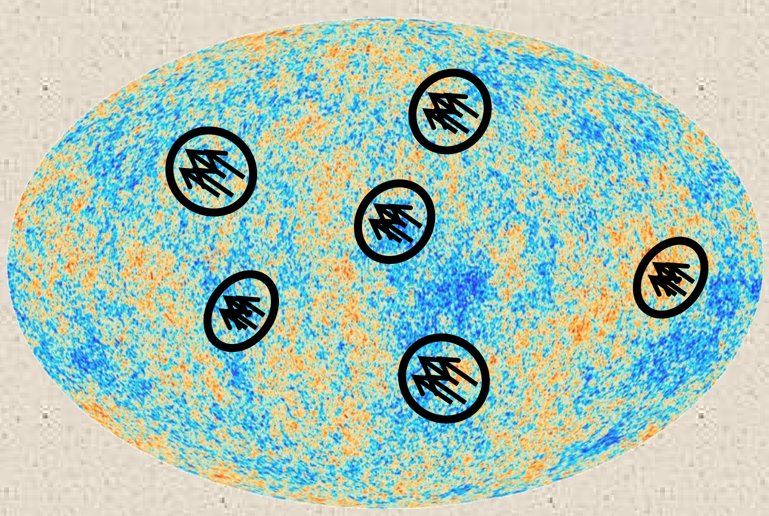
End of scaling $f_{\mathrm{eq}}(\sigma \to 0) = 1$

$\left.\begin{matrix} \rho_{A,\mathrm{end}}^{(\mathrm{eq})} \\ \zeta^{(\mathrm{eq})} \end{matrix}\right\}$ suppressed WRT $\left\{\begin{matrix} \rho_{A,\mathrm{end}}^{(\mathrm{out})} \\ \zeta^{(\mathrm{out})} \end{matrix}\right.$



Breaking the isotropy of the CMB

A cartoon



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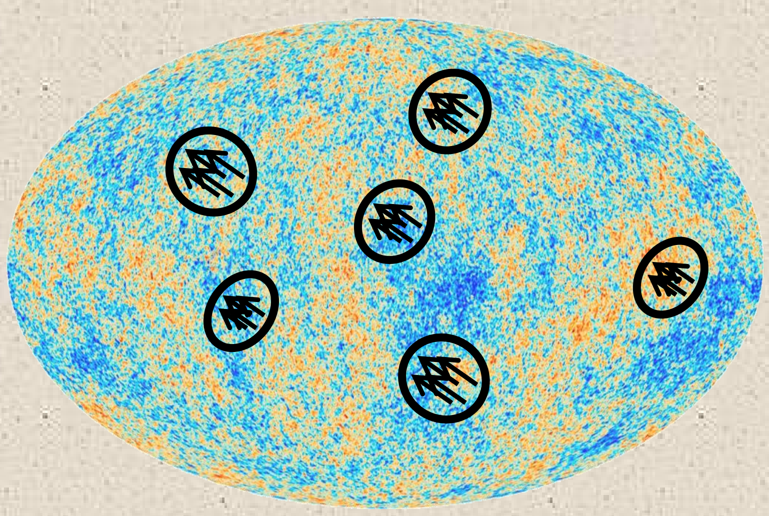

Correlated spatial variation of r

Full sky maps required with enough sensitivity (CORE,CMB-Pol,LiteBIRD)

$$r \sim 10^{-2} - 10^{-3}$$

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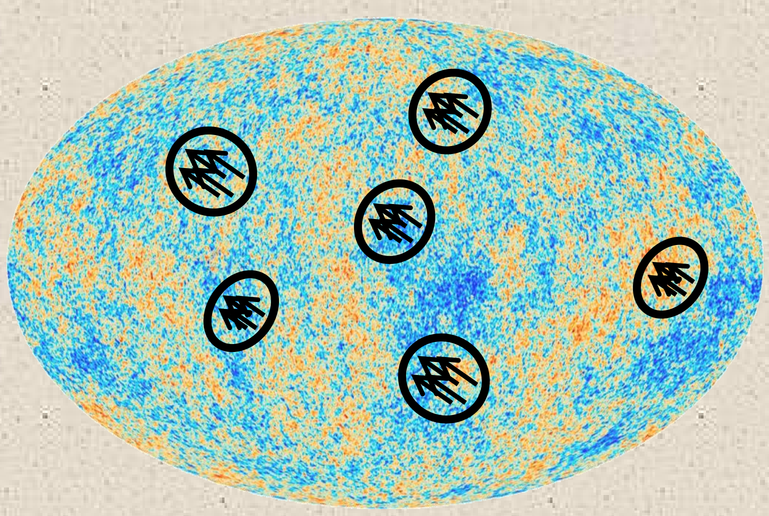

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Correlated parity violating signal

$$\mathcal{L}_v = f(\sigma)\left(-\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \frac{\gamma}{8}\widetilde{F}_{\mu\nu}F^{\mu\nu}\right) + \frac{1}{2}m^2 A_\mu A^\mu$$

Non-vanishing EB correlations

Conclusions

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(Local versions of inhomogeneous reheating , vector curvaton , …)

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CMB anomalies as an indirect probe of the inflaton dynamics + interactions

What is the prediction from motivated inflationary models?

Come to IberiCOS 2016 to find out!