Preheating and Gravitational Waves from Geometrical Destabilization

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Geometrical Destabilization

$$\boxed{\frac{m_s^2}{H^2} = \frac{V_{;ss}}{H^2} + 3\eta_\perp^2 + \epsilon_1 R_{fs} M_p^2}$$

mass of entropic perturbations

- turn rate – slow-roll parameter – field-space curvature

Renaux-Petel, KT 1510.01281

Minimal realization

$$\mathcal{L} = -\frac{1}{2}(\partial\varphi)^2\left(1+\frac{2\chi^2}{M^2}\right) - V(\varphi) - \frac{1}{2}(\partial\chi)^2 - \frac{1}{2}m^2\chi^2$$

inflaton   spectator

$$R_{fs} = -\frac{4}{M^2}\left(1+\frac{2\chi^2}{M^2}\right)^{-2} \xrightarrow{\text{trajectory } \chi=0} -\frac{4}{M^2}$$

$$m_s^2 = m^2 - 4\epsilon_1 H^2 \frac{M_p^2}{M^2} \xrightarrow{\epsilon_1 \nearrow} \epsilon_{1,c} = \frac{1}{4}\left(\frac{m}{H_c}\right)^2\left(\frac{M_p}{M}\right)^2$$

critical value at which m_s^2 goes **NEGATIVE**

Entropic perturbations with $k < k_c = a_c H_c$ grow **EXPONENTIALLY**

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$\chi = 0$ idealization $\xrightarrow[\text{equation}]{\text{Langevin}}$ $\langle \chi_c^2 \rangle = \left(\frac{H_c}{2\pi}\right)^2 \boxed{\Delta N_c}$

number of e-folds between the light ($m_s < H$) and unstable phase

- χ shifted away from zero and unstable; so are its perturbations, BUT
- R_{fs} reduced [curable]
- slow-roll e.o.m. $3H\dot{\varphi} + \left(1 + \frac{2\chi^2}{M^2}\right)^{-1} V' = 0$

  χ grows $\rightarrow$ φ slows down [generic]

Geometrical destabilization killed by negative feed-back loop

Grocholski, Kalinowski, Kolanowski, Renaux-Petel, KT, Vennin 1901.10468

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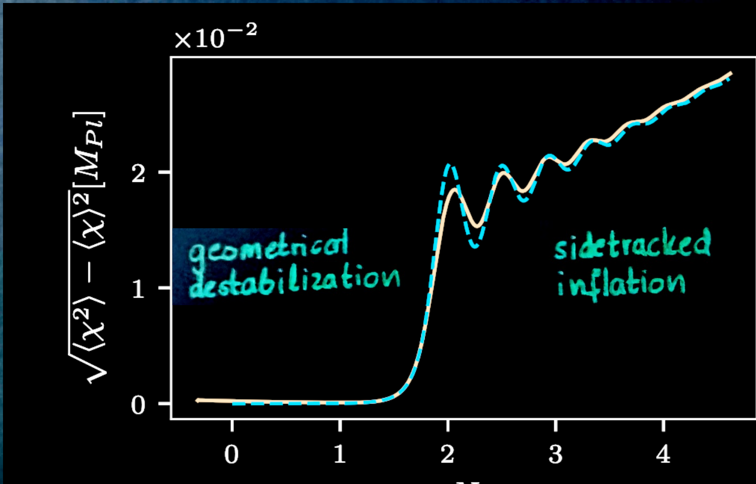

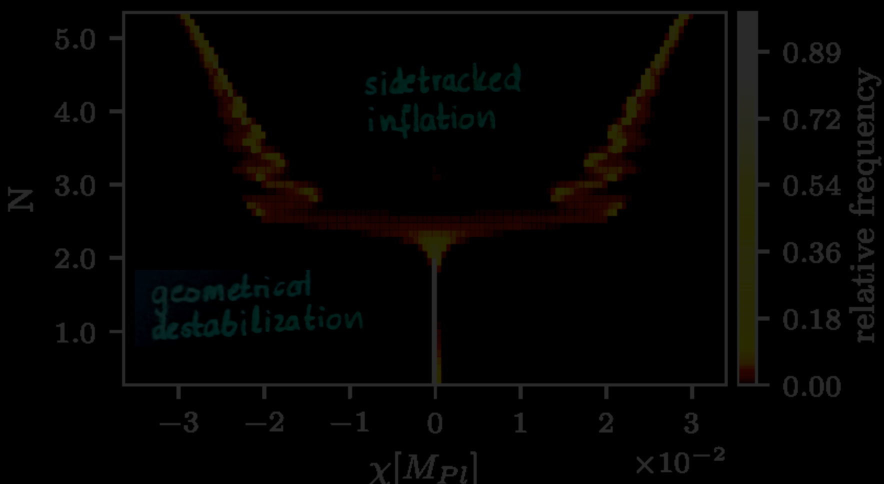

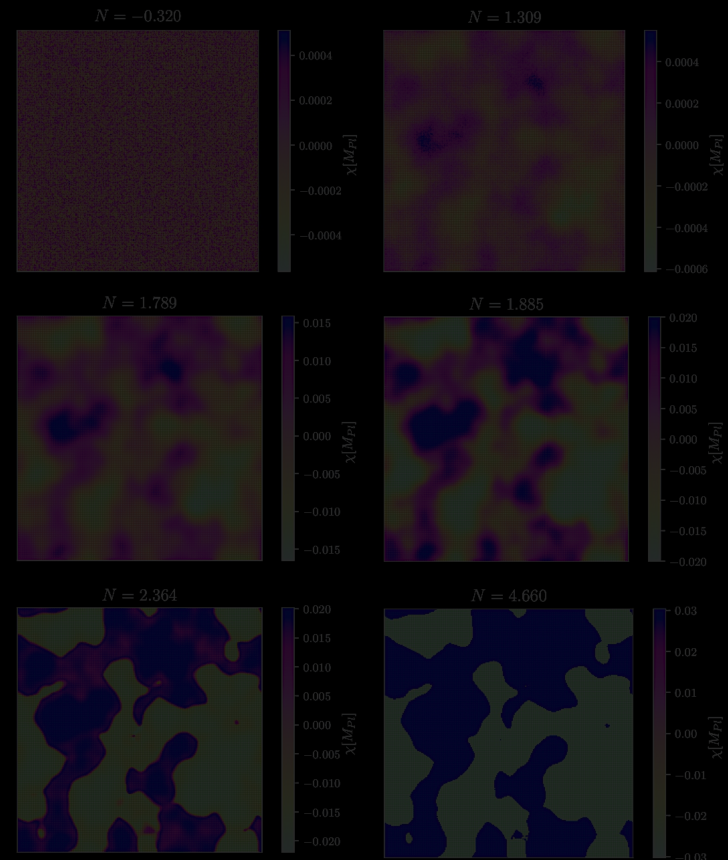

Krajewski, KT 2205.13487

$$\frac{m^2}{H_c^2} = 10^2$$

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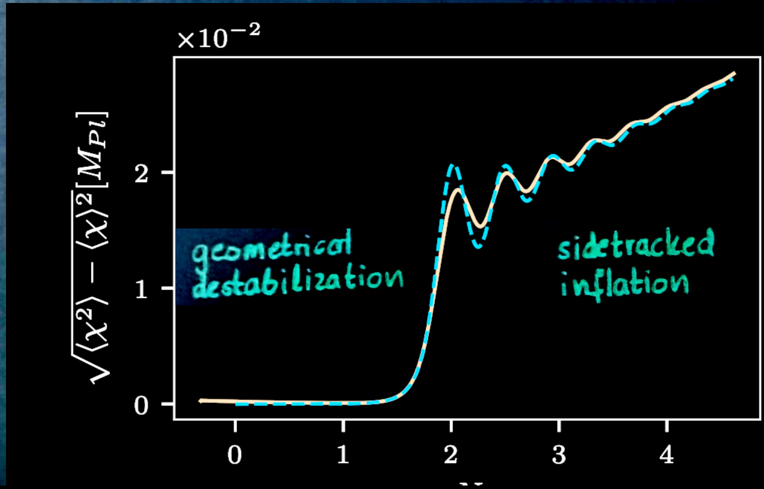

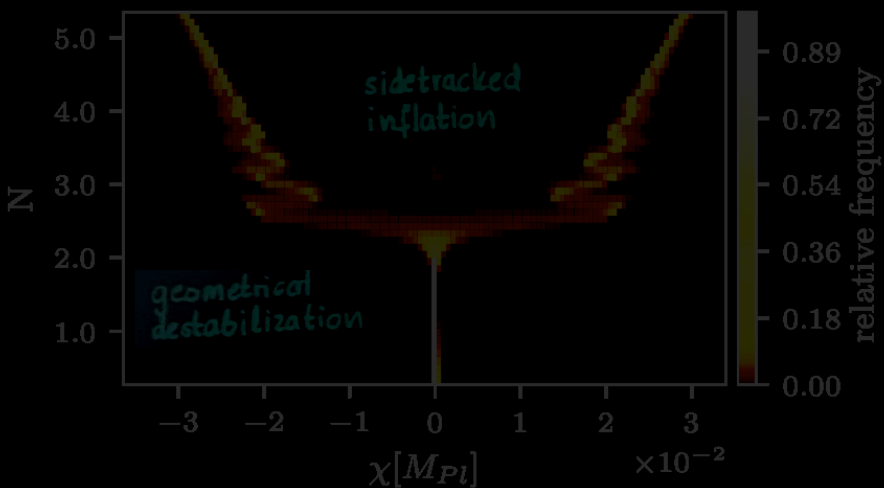

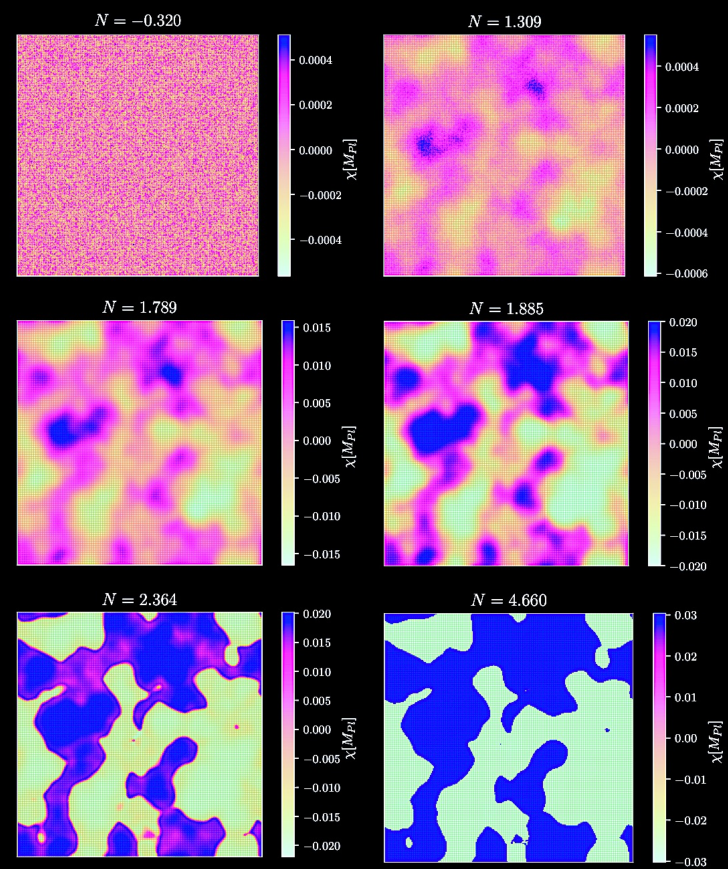

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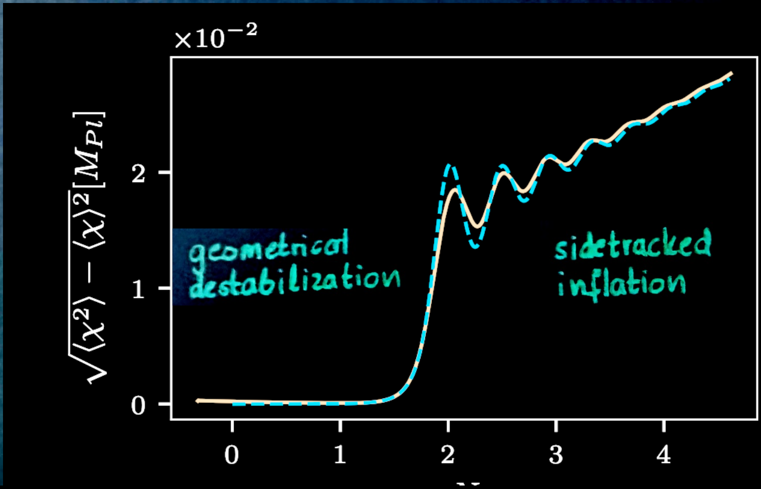

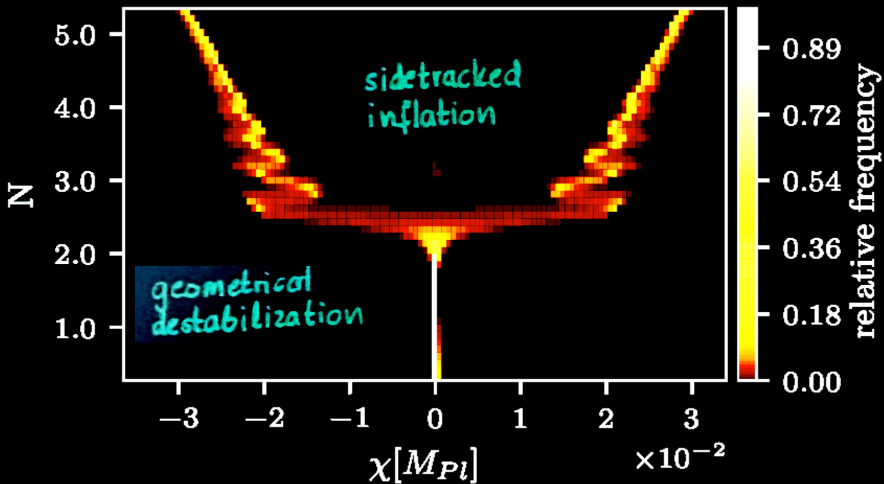

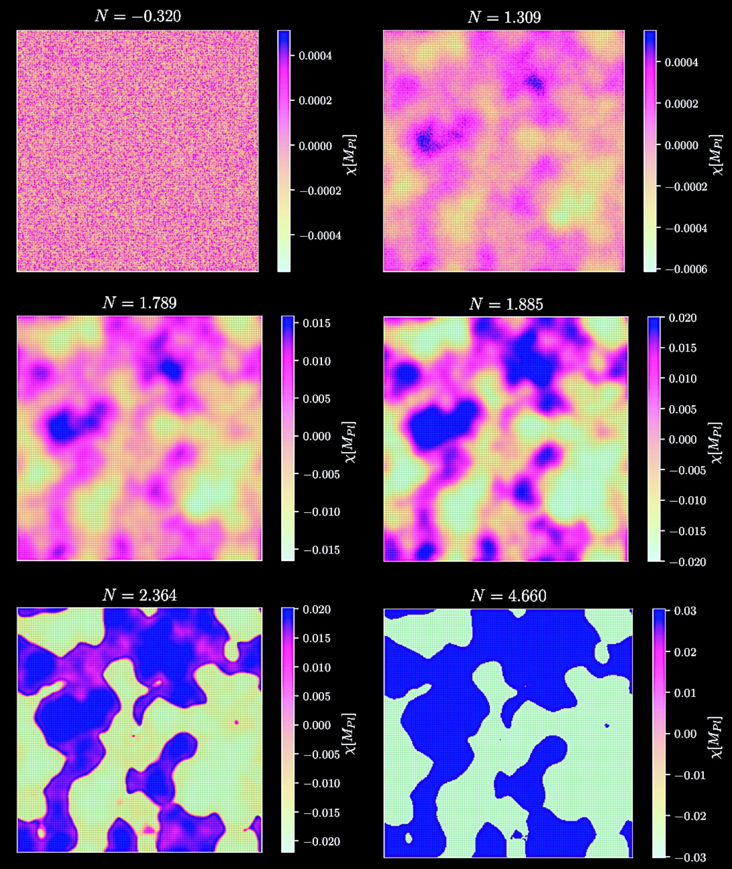

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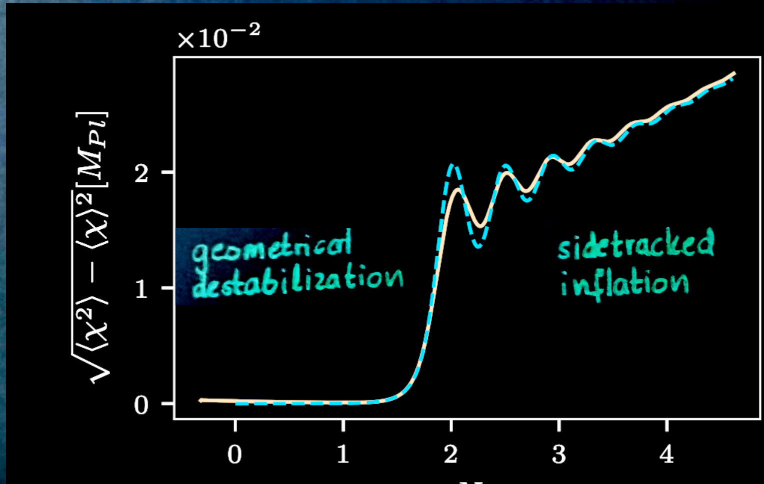

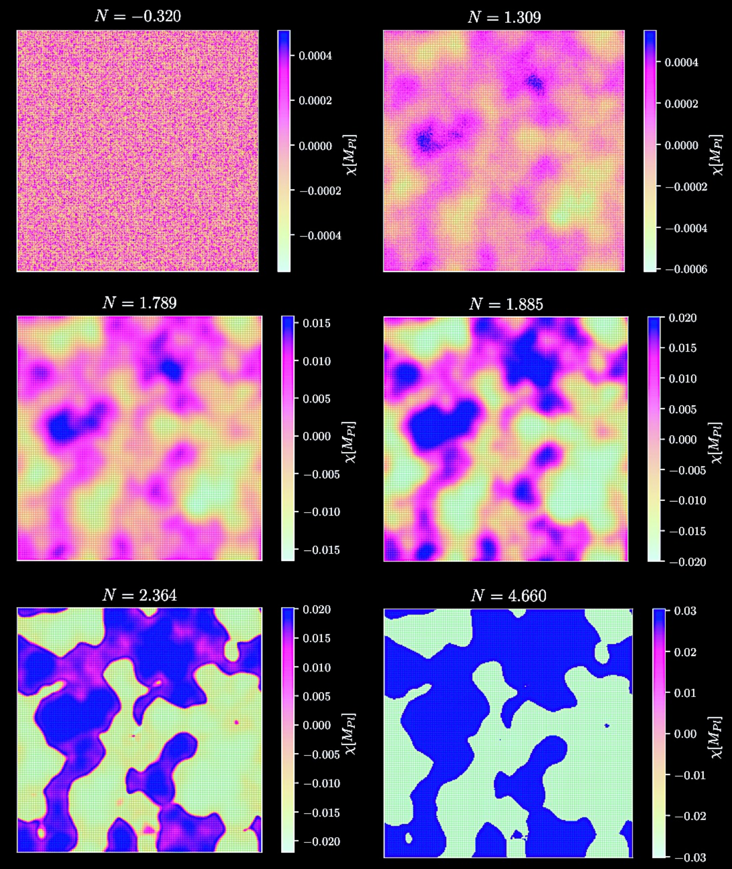

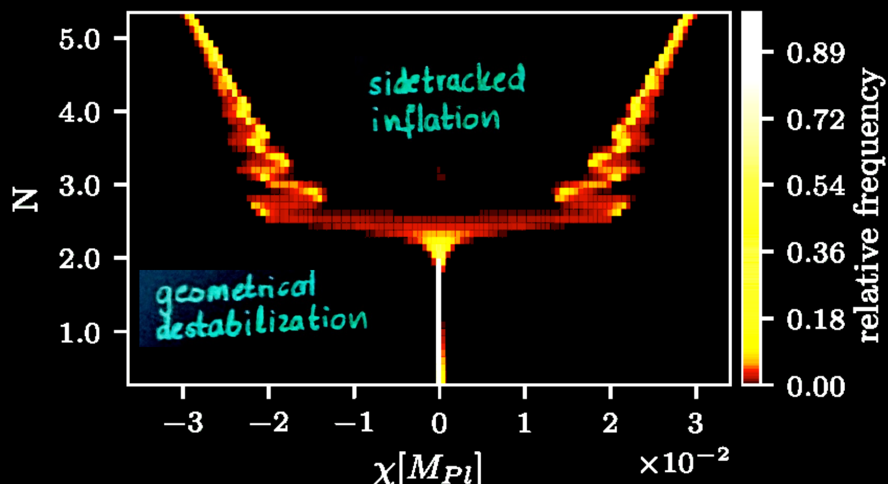

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$$K = -\frac{3\alpha}{2}\log\left[\frac{(T-\bar{T})^2}{4T\bar{T}}\right] + S\bar{S} \qquad W = \sqrt{\alpha}\,\mu\, S\left(\frac{T-1}{T+1}\right)^n$$

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with $\beta = \sqrt{\frac{2}{3\alpha}}\,M_p^{-1}$ and $M^4 = \alpha\mu^2 M_p^2$

- Field space is hyperbolic with $\boxed{R_{fs} = -\frac{4}{3\alpha}M_p^2}$

$\Rightarrow$ During inflation at CMB scales $\boxed{\varepsilon_1 \sim \alpha^2}$

- At the end of inflation $\varepsilon_1 \to 1$

  $\Rightarrow$ destabilization is possible !

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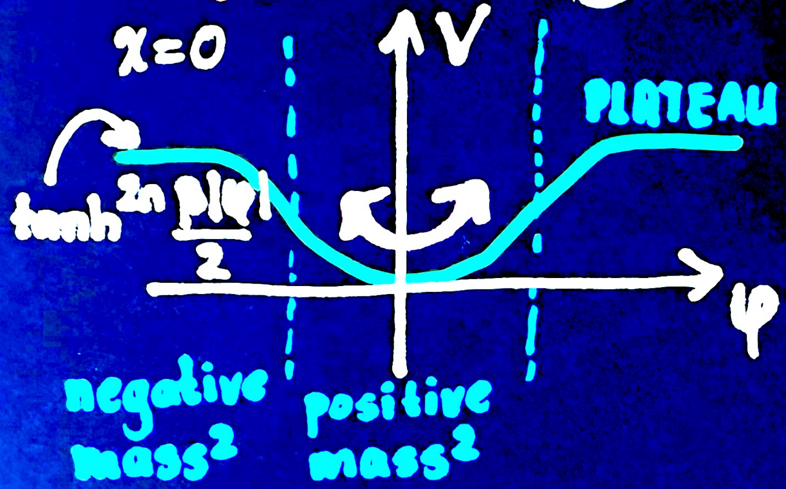
Reheating in α-attractors

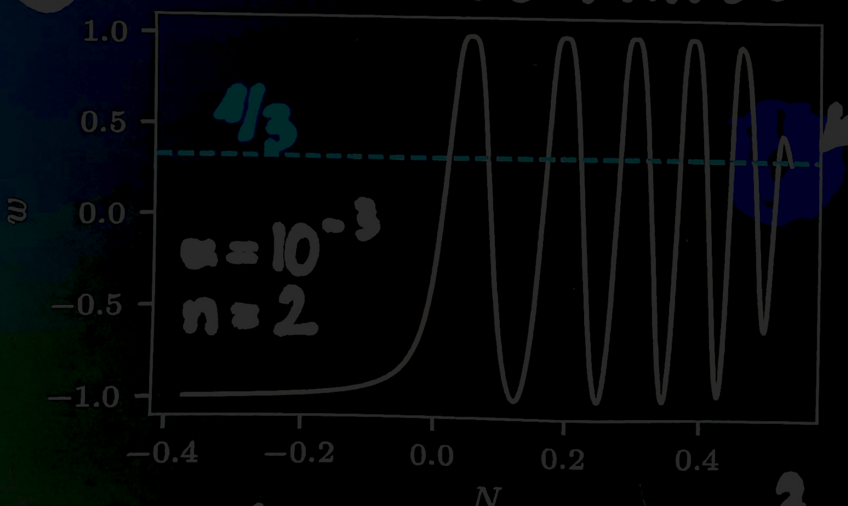


$$w = \frac{\langle p \rangle}{\langle \rho \rangle} : \frac{n-1}{n+1} \longrightarrow \frac{1}{3}$$

in a few e-folds ($n>1$)

Amin + Lozanov 2016 (without geometrical destabilization)

Our lattice simulations: REHEATING



$w \to \frac{1}{3}$ in a fraction of e-fold

Instability so strong that we cannot resolve the dynamics of perturbations.

Typical for $\alpha \leq 10^{-3}$

Krajewski, KT, Wieczorek 1801.01786

Krajewski, KT 2204.12909

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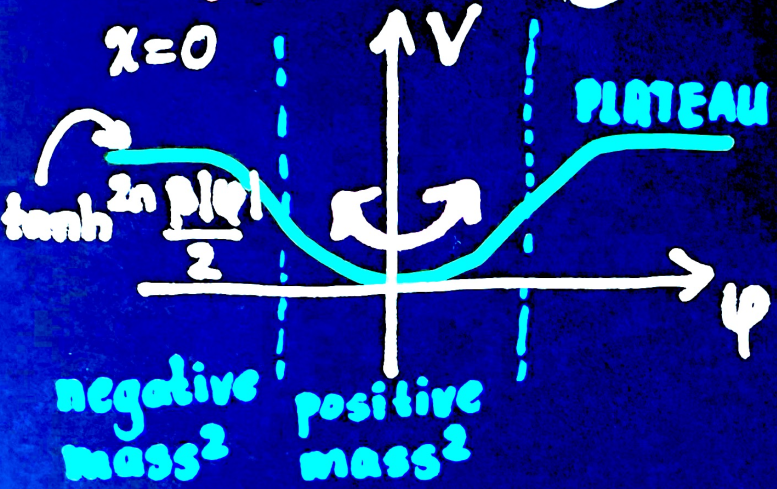

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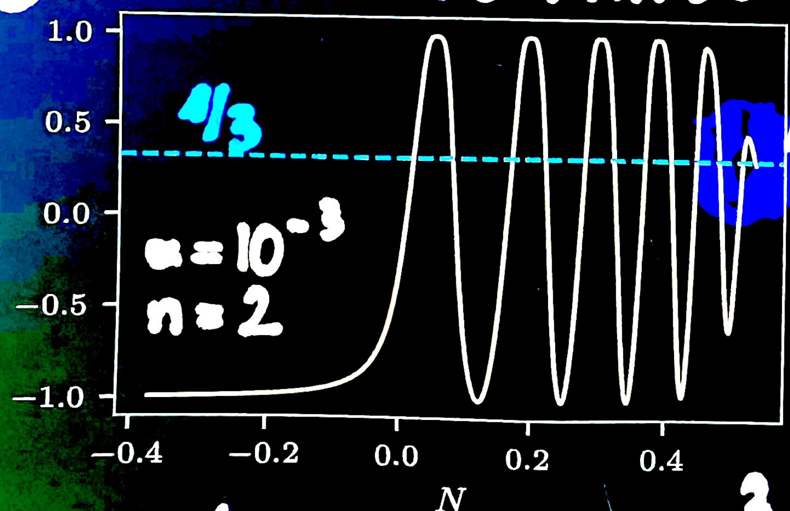

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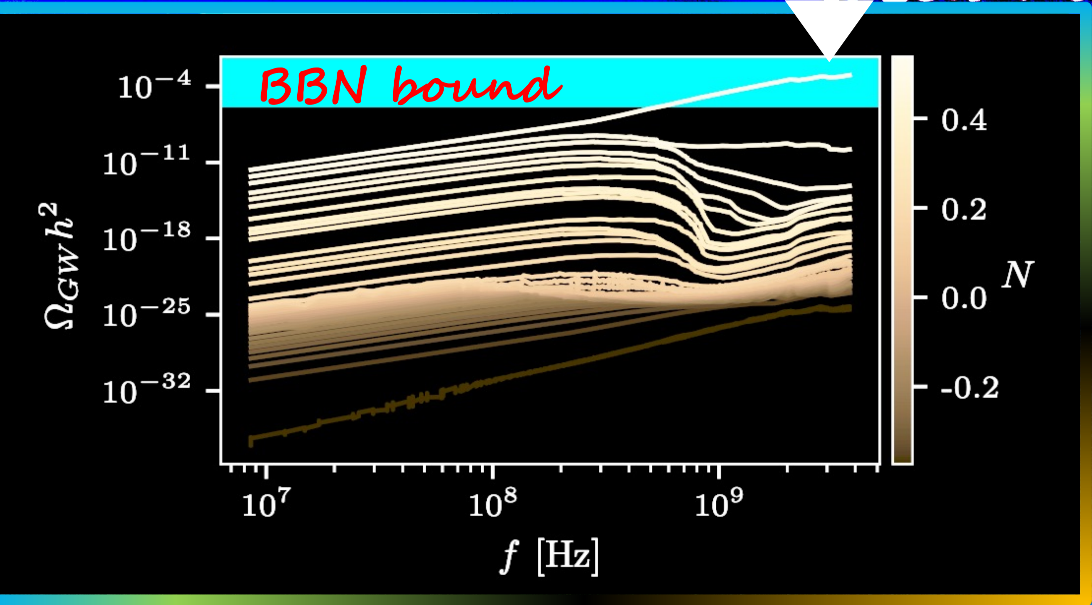
Gravitational waves in α-attractors

$$h''_{ij} + \left(k^2 - \frac{a''}{a}\right) h_{ij} = \frac{2a}{M_p^2} T^{TT}_{ij} \qquad T_{ij} = \cosh^2\beta\chi \, \partial_i\varphi \, \partial_j\varphi + \partial_i\chi \, \partial_j\chi$$

solver accuracy



- Unstable scalar perturbations feed tensor perturbations
- Extreme growth of gravitational waves
- Excluded by BBN bounds ?

Krajewski, KT 2204.12909

Conclusions

Geometrical Destabilization

- **does not stop inflation**
  but may kick it into a different phase
- **can help reheat the Universe**
  e.g. in α-attractor models
- **can produce gravitational waves**
  too much of them ?