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RESONANT BACKREACTION IN AXION INFLATION

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AXION INFLATION

- Theoretically and phenomenologically appealing to drive inflation by axion-like fields

- Generic coupling to (dark) U(1) gauge fields yields rich pheno

$$\mathcal{L} = -\frac{1}{2}\partial_\mu\phi\partial^\mu\phi - \frac{1}{4}F_{\mu\nu}F^{\mu\nu} - V(\phi) - \frac{\alpha}{4\Lambda}\phi F_{\mu\nu}\tilde{F}^{\mu\nu}$$

> **Backreaction inflationary dynamics**, inflating on steep potential, duration inflation, changes (ns, r).
> **Exponential production scalar, gauge & tensor modes, primordial black holes**, primordial magnetic fields, chiral gravitational waves, large primordial non-Gaussianities, efficient preheating, baryogenesis

[Anber, Sorbo '06] [Anber, Sorbo '10] [Barnaby, Peloso '11] [Barnaby, Pajer, Peloso '11] [Linde, Mooij, Pajer '13] [Adshead, Giblin, Scully, Sfakianakis '16] [Jimenez, Kamada, Schmitz, Xu, '17] [Domcke, Muia, Pieroni, Witkowski, '17]

GAUGE FIELD PRODUCTION & BACKREACTION I

[Anber, Sorbo '10]

- Exponential gauge field production in inflationary background

$$A''_\pm(\vec{k}) + (1-\epsilon)A'_\pm(\vec{k}) + \frac{k}{aH}\left(\frac{k}{aH} \pm 2\lambda\xi\right)A_\pm(\vec{k}) = 0$$

$$\xi \equiv \frac{\alpha\lambda\phi'}{2\Lambda}$$

tachyonic instability

(1) Backreaction on inflationary dynamics (relevant for $\xi > 4.7$)

$$\ddot{\phi} + 3H\dot{\phi} + \frac{\partial V}{\partial \phi} = \frac{\alpha}{\Lambda}\langle \vec{E}\cdot\vec{B}\rangle \quad \longleftarrow \quad \langle \vec{E}\cdot\vec{B}\rangle \sim -\lambda H^4 \frac{e^{2\pi\xi}}{\xi^4}$$

new friction term

GAUGE FIELD PRODUCTION & BACKREACTION II

[Barnaby, Peloso '11]

- Exponential gauge field production in inflationary background

$$A''_\pm(\vec{k}) + (1-\epsilon)A'_\pm(\vec{k}) + \frac{k}{aH}\left(\frac{k}{aH} \pm 2\lambda\xi\right)A_\pm(\vec{k}) = 0$$

$$\xi \equiv \frac{\alpha\lambda\phi'}{2\Lambda}$$

tachyonic instability

(2) Backreaction on inflationary perturbations (relevant for ξ > 2.5)

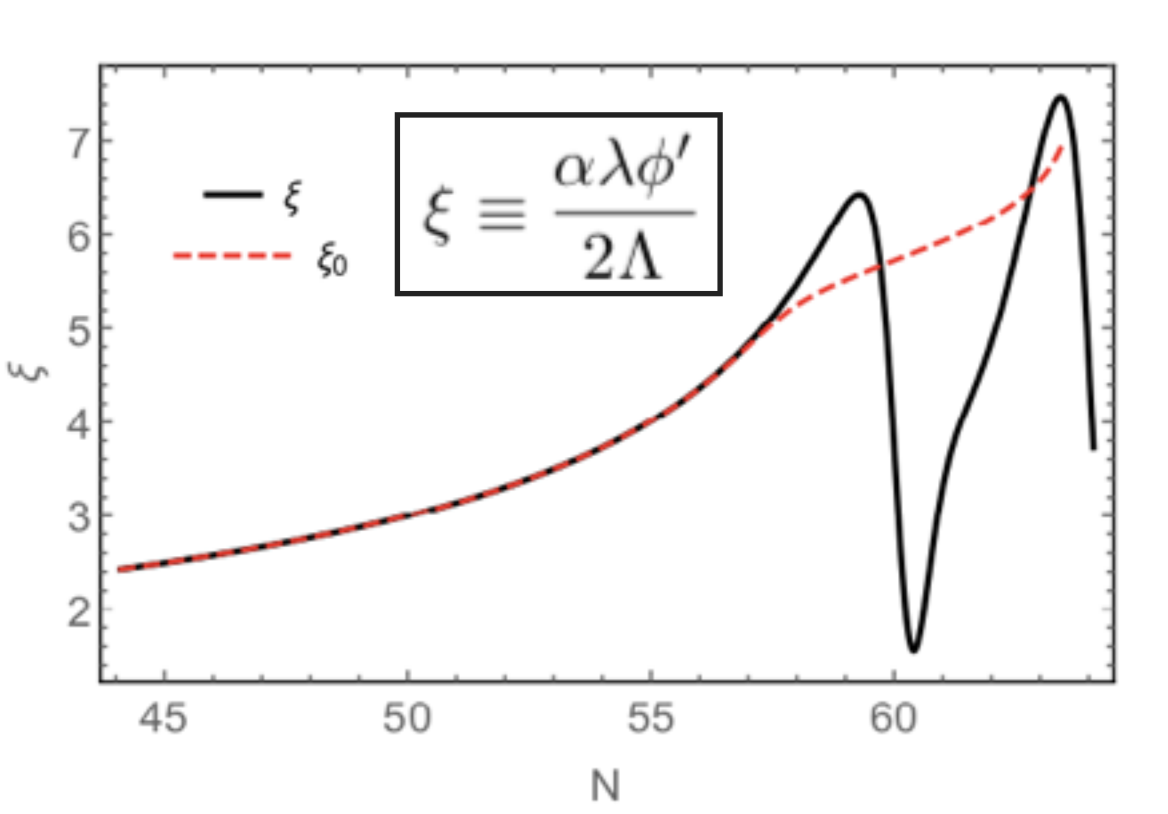
$$\delta\phi'' + 3\delta\phi' - \frac{\alpha N_{,\phi}}{\Lambda H^2}\frac{\partial\langle\vec{E}\cdot\vec{B}\rangle}{\partial N}\delta\phi = \frac{\alpha}{\Lambda H^2}\left(\vec{E}\cdot\vec{B} - \langle\vec{E}\cdot\vec{B}\rangle\right)$$

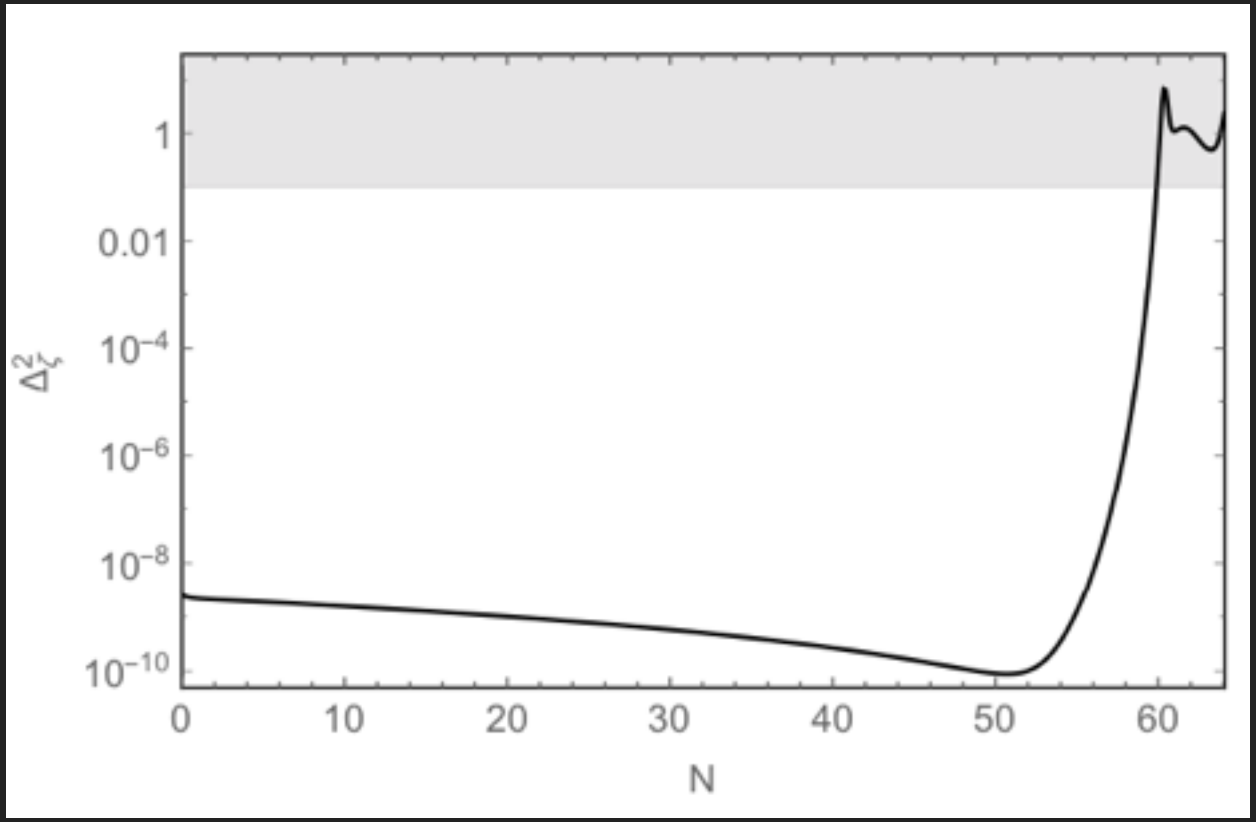
source term

OSCILLATORY FEATURES

- We observe oscillatory features in both ξ and <EB>, reflected in P_ζ :

See also [Cheng, Lee, Ng '16] [Notari, Tywoniuk '16] [Dall 'Agata, Gonzalez-Martin, Papageorgiou, Peloso '19]

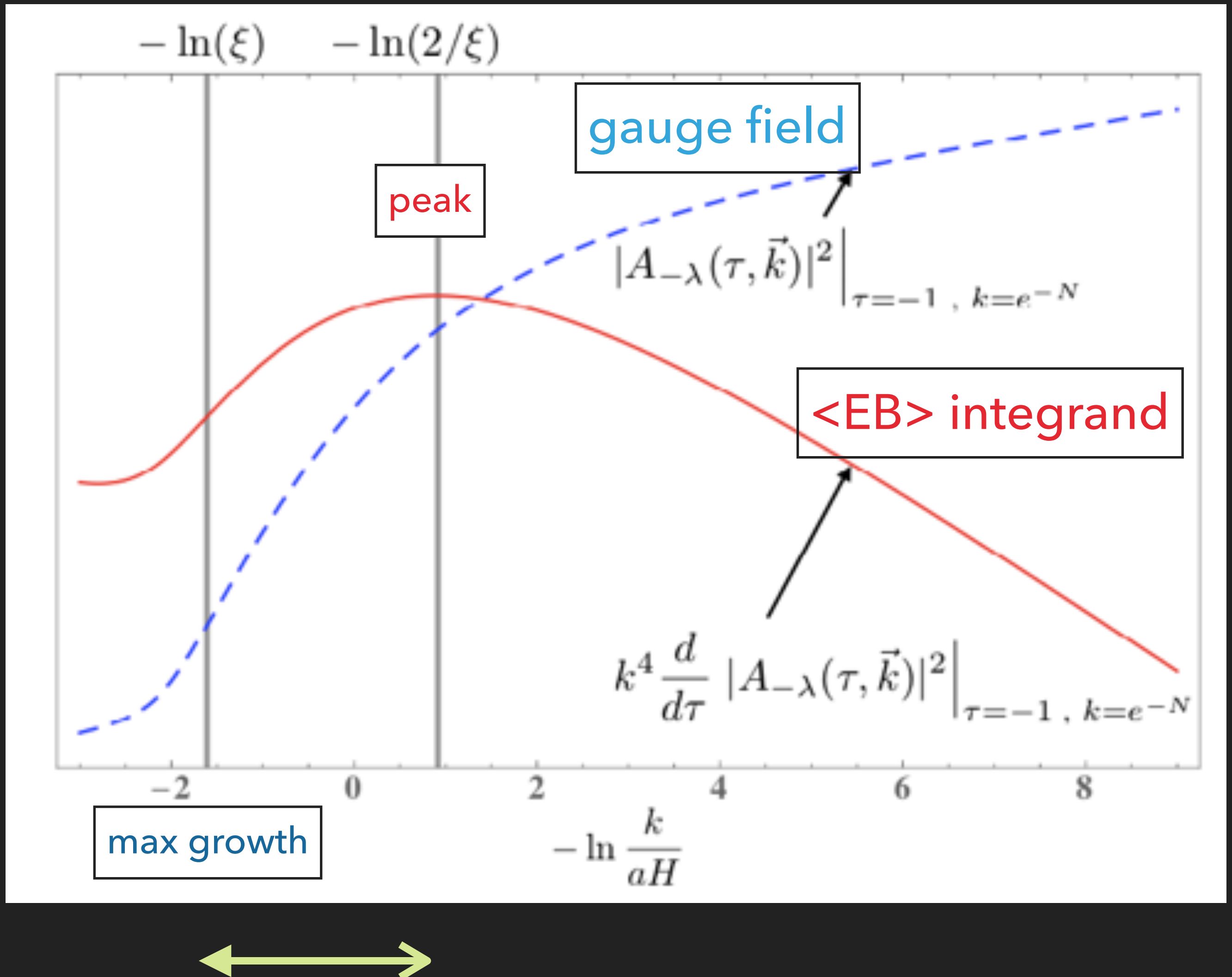




$V \sim \varphi^2$; $\alpha/\Lambda = 20$ constant ξ assumption breaks down

EXPLANATION: RESONANT GAUGE FIELD PRODUCTION

- <E B> responds with a time delay to a change in ξ



$$\Delta N_\xi \sim \ln \xi^2/2$$

EXPLANATION: RESONANT GAUGE FIELD PRODUCTION

- The system will find resonance at $\omega = \pi/\Delta N_\xi$ (for ξ >4.7)

Increase ξ suppresses <EB> at ΔN_ξ e-folds later

$$\Delta\langle\vec{E}\cdot\vec{B}\rangle \sim -\Delta\xi(N - \Delta N_\xi)$$

$$\ddot{\phi} + 3H\dot{\phi} + \frac{\partial V}{\partial \phi} = \frac{\alpha}{\Lambda}\langle\vec{E}\cdot\vec{B}\rangle$$

$$\Delta\xi \sim \Delta\langle\vec{E}\cdot\vec{B}\rangle$$

Backreaction term updates value of ξ

CONCLUSION

- Axion inflation generically experiences a resonant enhancement of gauge field production. This impacts observables at the end of inflation
- For more details:

  - Analytical understanding of time delay $\Delta N \sim \log(\xi^2/2)$ + more detailed argumentation resonance
  - Detailed description of our procedure to solve integro-differential system
  - Computation of the scalar power spectrum (significantly larger amplitude than previous estimates)
  - Qualitative discussion on constraints from non-observation primordial black holes

See our paper!

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Thanks!

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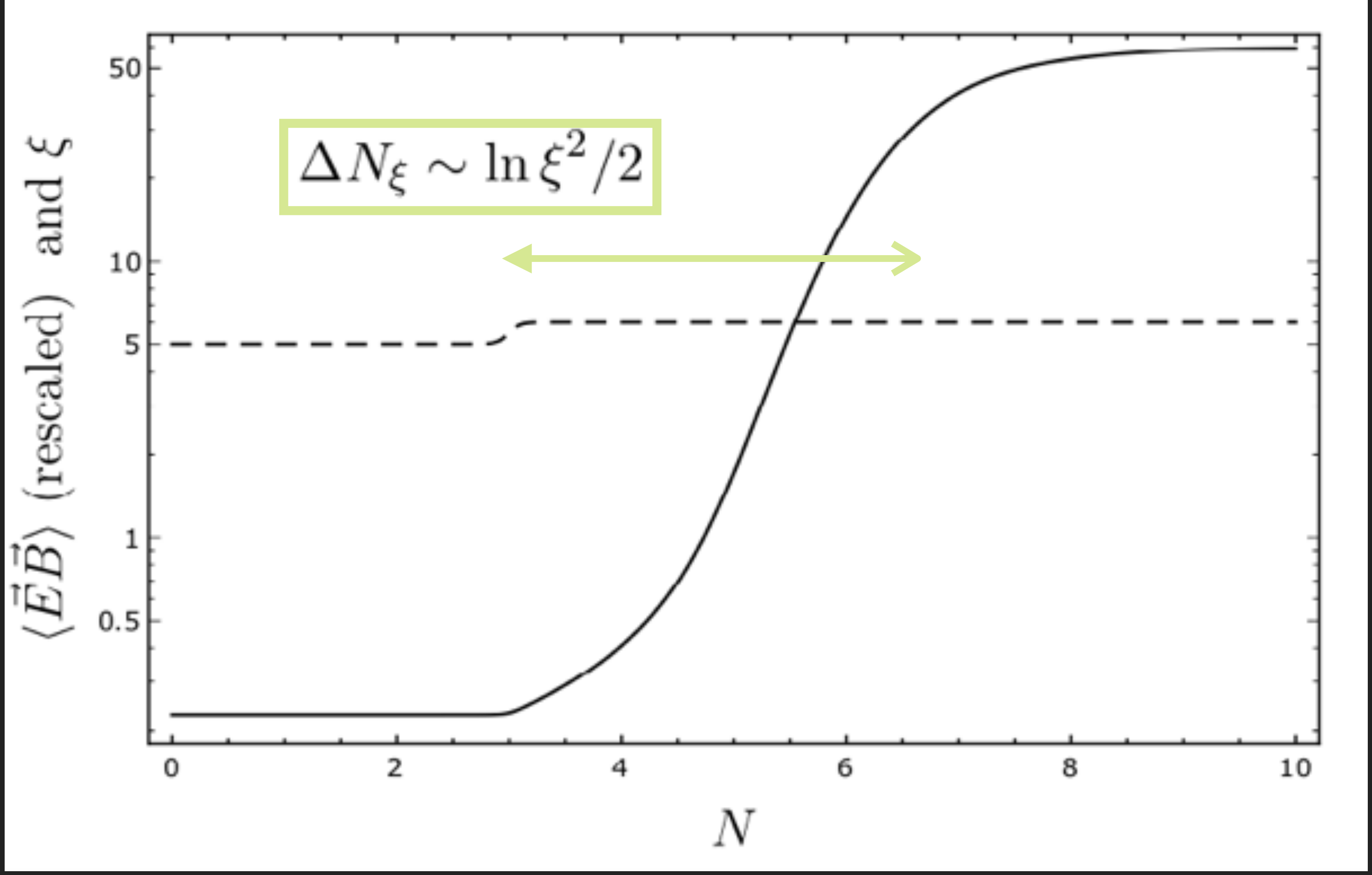
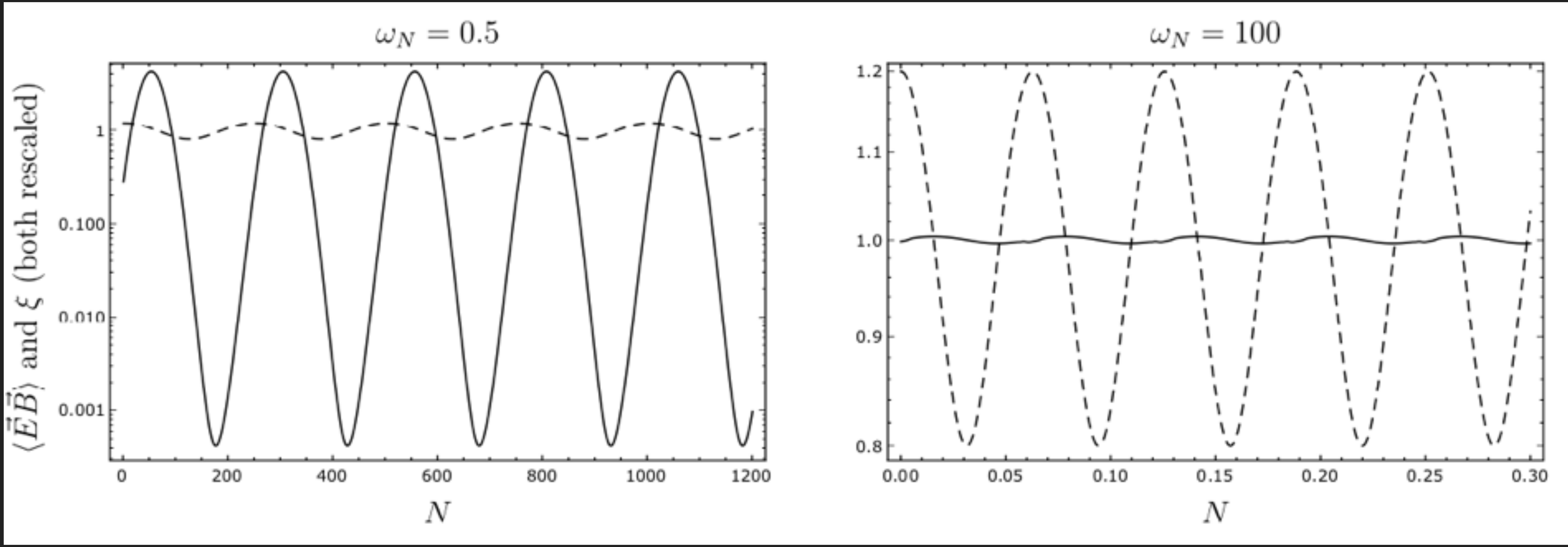
TIME LAG

- Response of <EB> to a sudden change in ξ



TIME LAG

- Response of <EB> to a periodically varying ξ



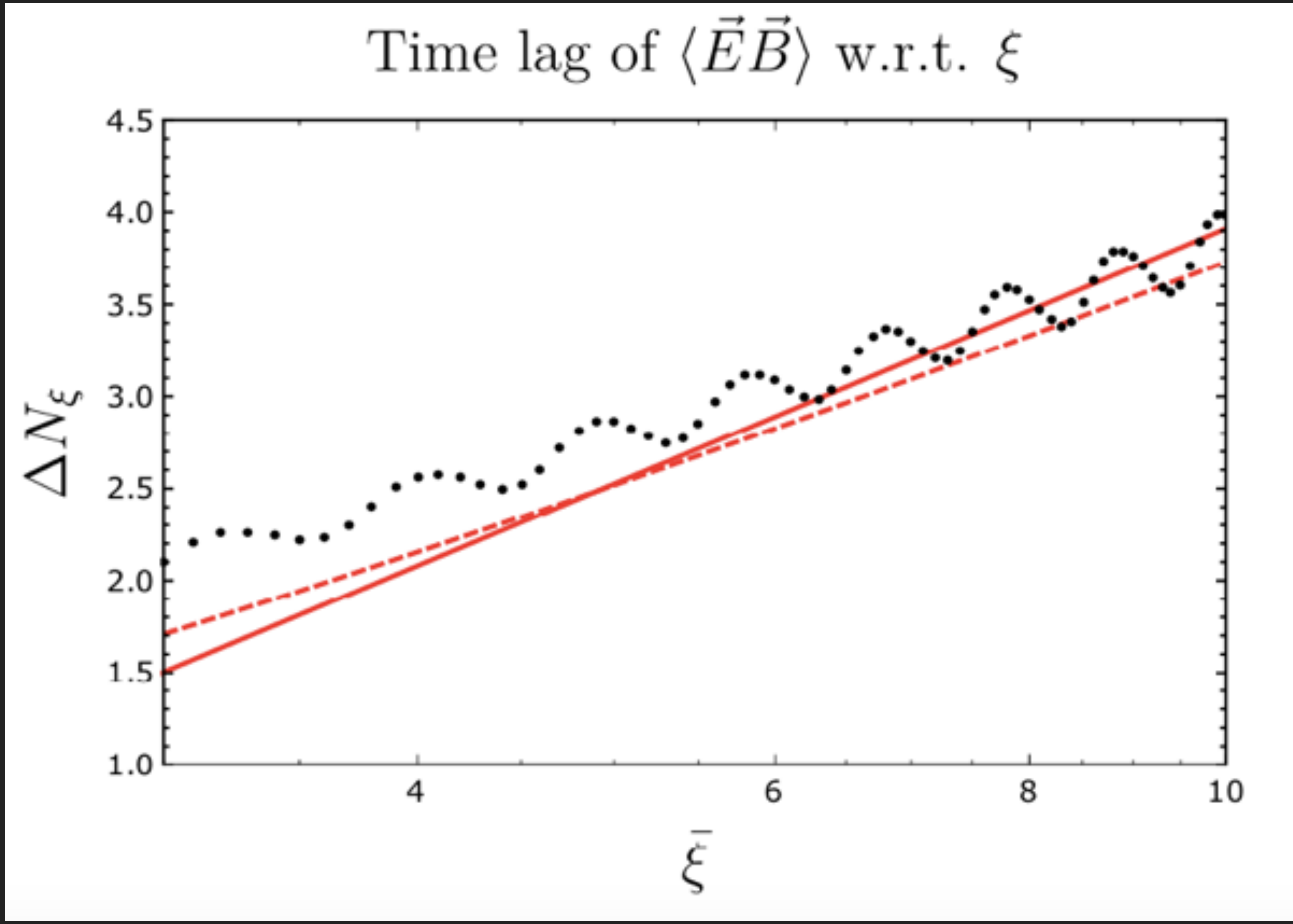
Near critical frequency - significant response and phase shift

High frequency - response averages out

$$\Delta N_\xi \sim \ln \xi^2/2$$

TIME LAG

- Response of <EB> to a periodically varying ξ with $\omega_N \sim 0.2$



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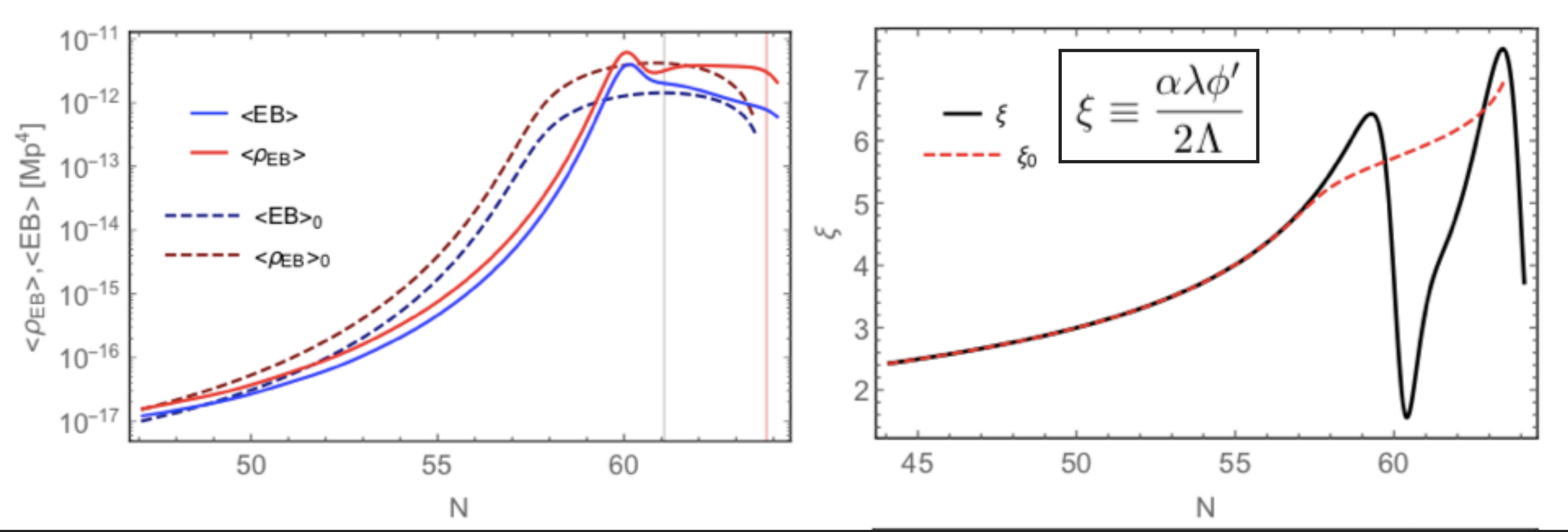

$V \sim \varphi^2$; $\alpha/\Lambda = 20$ constant ξ assumption breaks down

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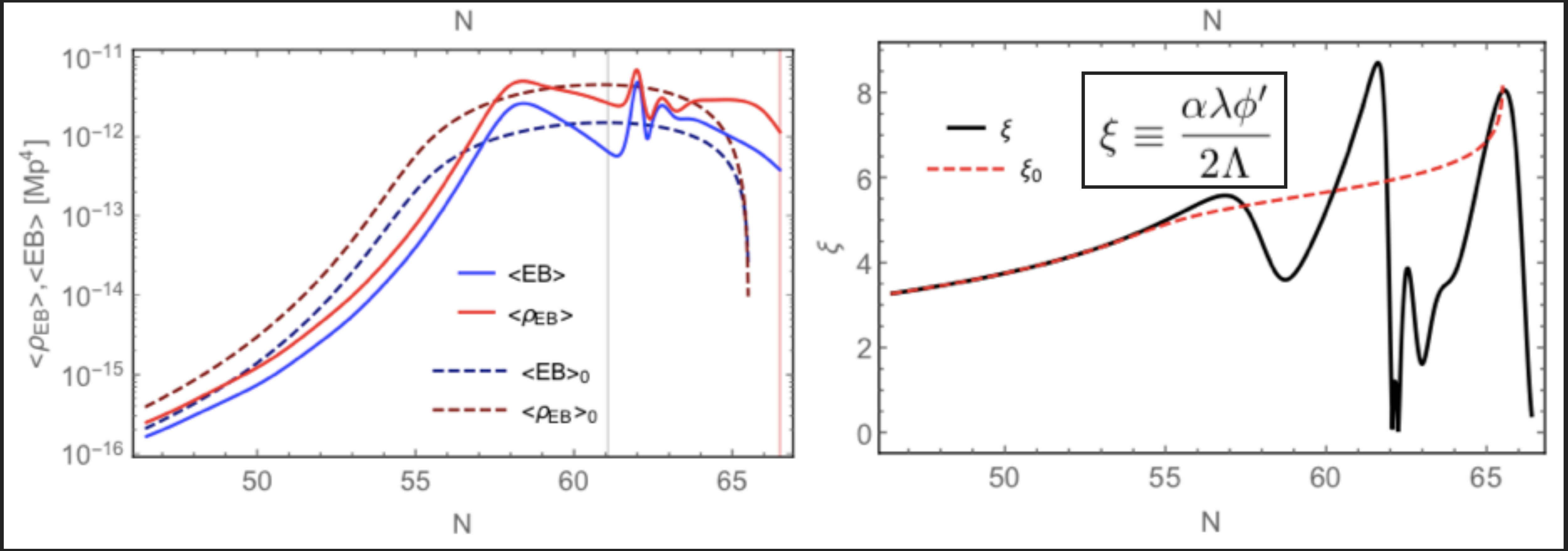

$V \sim \varphi^2$; $\alpha/\Lambda = 25$ constant ξ assumption breaks down