Vacuum particle production

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Vacuum Particle Production

- Quantum Fields living in an external classical field has a fundamental implications: **Vacuum Particle production**
- In particular QF in a classical curved space-time $g_{\mu\nu}$

- Expanding Universe (Parker, 1966)

- Black Holes (Hawking, 1975)

- Primordial density perturbation in inflation(Mukhanov and Chibisov, 1981)

- (Pre)heating
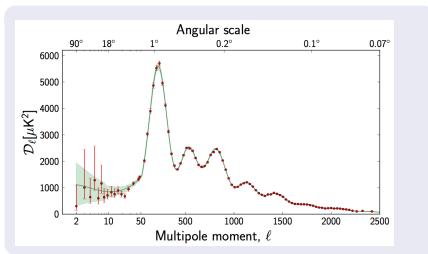
Example: (P)Reheating

- Coupling the initial inflaton after inflation into the SM matter
- Inflaton $\Phi(t)$ classical background field
- Oscilating down the potential
- Couple to matter with yukawa coupling $+g_Y \Phi \bar{\psi}\psi$
- Implies particle production for non-adiabatic evolution of Φ
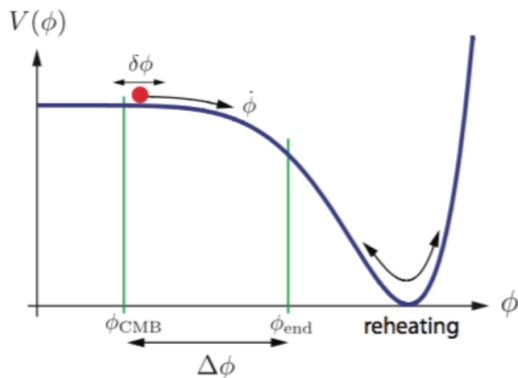
Backreaction

- Particle production implies non vanishing $\langle \bar{\psi}\psi \rangle$, $\langle T_{\mu\nu} \rangle$ and $\langle j^\mu \rangle$
- These are usually sources for the original classical field through semiclasical (Einstein, Maxwell, Klein-Gordon...) equations

backreaction equations for reheating

$$
\begin{aligned}
(i\underline{\gamma}^\mu \nabla_\mu - m)\psi &= g\Phi\psi \\
G^{\mu\nu} &= -8\pi G(\langle T_m^{\mu\nu} \rangle + T_\phi^{\mu\nu}) \ , \\
\Box\Phi + \frac{\partial V}{\partial \Phi} &= -g\langle \bar{\psi}\psi \rangle
\end{aligned}
$$

- Matter created changes gravity, gravity changes particle creation, matter created changes gravity...
- **BUT, usual local observables are UV divergent**

Adiabatic Regularization

Example

- $ds^2 = dt^2 - a^2(t)d\vec{x}^2$ and $\mathcal{L}_{matter} = \sqrt{-g}\,(\nabla\phi)^2$
- $\rho = \langle T_{00} \rangle \sim \int_{-\infty}^{\infty} dk^3 \;\; 2\omega - \frac{\dot{a}^2}{\omega a^2} \to$ DIVERGENT

Need of a Regularization method$\to$ **Adiabatic Regularization**

📄 A. Del Rio, **A. F.**, J. Navarro-Salas and F. Torrenti Phys. Rev. D 95, 105003 (2017)

(Renormalized) backreaction equations for reheating

$$
\begin{aligned}
(i\underline{\gamma}^\mu \nabla_\mu - m)\psi &= g\Phi\psi \\
G^{\mu\nu} &= -8\pi G(\langle T_m^{\mu\nu}\rangle_{ren} + T_\phi^{\mu\nu})\,, \\
\Box\Phi + \frac{\partial V}{\partial\Phi} &= -g\langle\bar{\psi}\psi\rangle_{ren}
\end{aligned}
$$

Real numerical calculations for realistic inflation models (Work in progress).

Schwinger Effect+Backreaction

2D QED + Electric Pulse

$$(i\underline{\gamma}^\mu D_\mu - m)\psi = 0$$
$$\nabla_\mu F^{\mu\nu} = -q\langle\bar{\psi}\underline{\gamma}^\nu\psi\rangle_{ren} ,$$
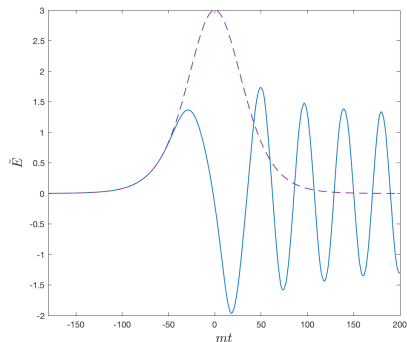

- Non perturbatic QED. Not detected yet (High Intensity lasers (XFEL))

- Posible magnetogenesis (Work in Progress)

📄 **A. F.** and J. Navarro-Salas Phys.Rev. D97 125012 (2018)

📄 J. F. Barbero G., A. F., J. Navarro-Salas, E. J. S. Villaseñor, arXiv:1805.05107

THANK YOU AND SEE YOU IN VALENCIA!