Inflationary Gravity Waves with ADVANCED LIGO

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Old Inflation

The first inflationary model was proposed by Alan Guth in 1980 [1].
**Old Inflation Failed**

- No Reheating
- Swiss Cheese Universe
- Why? Constant nucleation rate, $\Gamma$, models fail due to opposing constraints: $\sim 60$ e-folds vs percolation (requires $\ll 1$ e-fold) [2]
Solutions to Problem

- To overcome the problems faced by “old” inflation and maintain a First-Order Phase Transition, new models were proposed with a time-dependent nucleation rate.
- The time dependence has been proposed by Adams and Freese (1990) and Linde (1990) to arise from multi-field interactions [3,4].
- Other First-Order Phase Transition Models that include a time-dependent nucleation rate are extended inflationary models.

M. Cortes and A. Liddle, Phys. Rev. D 80, 083524
• Gravitational Wave energy spectrum:

\[
h^2 \Omega_{GW}(f) \equiv \begin{cases} 
    h^2 \Omega_0^{\text{peak}} \cdot 38 \left( \frac{f}{f_0^{\text{peak}}} \right)^3 & \text{if } f < 10^{-5} f_0^{\text{peak}} \\
    h^2 \Omega_0^{\text{peak}} \cdot \frac{3.8}{1 + 2.8 \left( \frac{f}{f_0^{\text{peak}}} \right)} & \text{if } f \geq 10^{-5} f_0^{\text{peak}}
\end{cases}
\]

• Peak frequency and amplitude:

\[
f_0^{\text{peak}}(\rho_v, \chi) = 9.88 \times 10^{-8} \left( \frac{\rho_v^{1/4}}{1 \text{ GeV}} \right) \frac{1}{\chi} \text{ Hz}
\]

\[
h^2 \Omega_0^{\text{peak}}(\chi) = 6.9 \times 10^{-8} h^2 \chi^2
\]

(Following Results of Huber and Konstandin [5])
Parameters of the GW spectrum

The Gravitational Wave energy spectrum is characterized by 2 parameters:

- $\chi = \text{Number of e-folds that the universe is stuck here.}$
- $\rho_v = \text{Energy density difference between the false and true vacuum.}$
Results

GW energy spectrum for $\rho_v^{1/4} = 10^{8.5}$ GeV

$\chi = 1.0$
$\chi = 0.31$
$\chi = 0.04$

Adv. LIGO
Results

GW energy spectrum for $\chi = 1$

$\rho_v^{1/4} = 10^4$ GeV  $\rho_v^{1/4} = 10^{8.5}$ GeV  $\rho_v^{1/4} = 10^{11}$ GeV

Adv. LIGO
Results

Parameter space \(\{\chi, \rho\} \) projected to be measured by Adv. LIGO
Future Work: Slower Phase Transition

- Calculate GW energy spectrum for $1<\chi<3.4$
- Since $\Omega_{GW}$ scales as $\chi^2$, then potential larger signal.
- Work will be done by simulations (Giblin) and analytically (2-bubble collisions)
Future Work: Chain Inflation

- Another solution to the problem of ~ 60 e-folds vs percolation is Chain Inflation
- Peak frequency and amplitude:

\[
\begin{align*}
    f_{n,\text{peak}} &= 0.23 \frac{H_n}{\chi} \\
    \Omega_{n,\text{peak}} &= 0.002 h^2 \frac{\rho \chi^2}{\rho_c n}
\end{align*}
\]

- Total GW energy density is given by:

\[
h^2 \Omega_{GW}(f) = \sum_{m=1}^{N-1} h^2 \Omega_{n,0}(f)
\]

- Look for Oscillations and compare to Planck Data
Thank You!
References


