Dark Matter production from Phase Transitions

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First-Order Phase Transitions

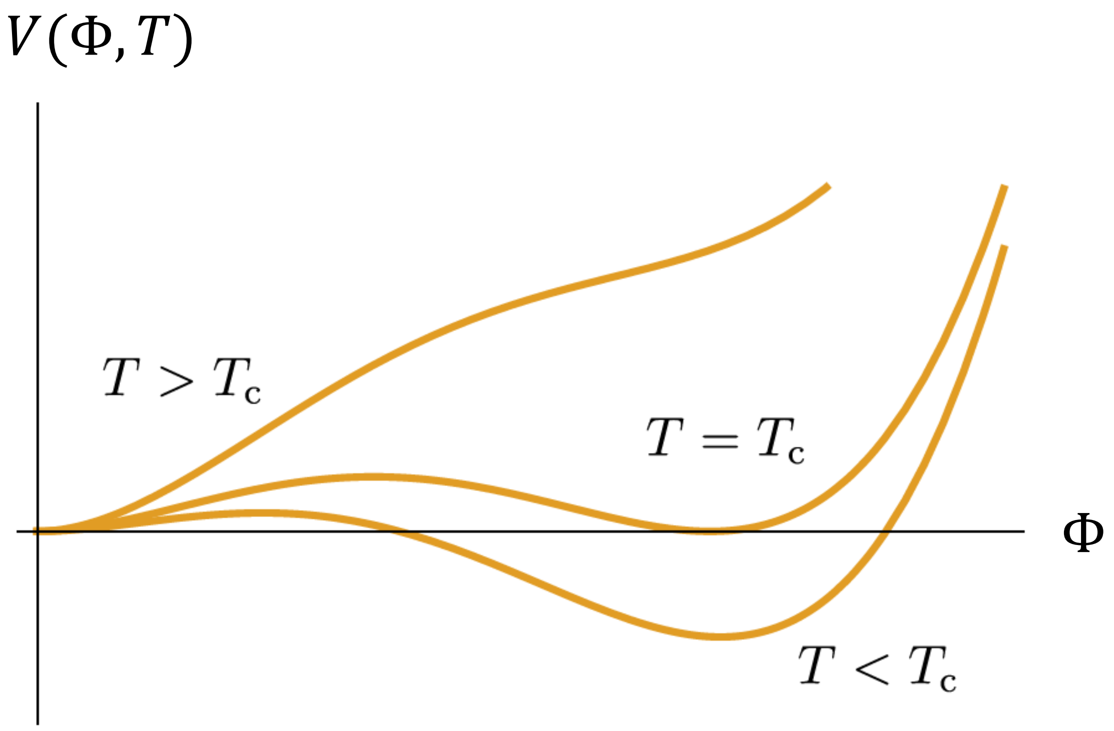
Fundamentals

- The field undergoing the transition acquires a non-zero vacuum expectation value (vev).

- The field, Φ, is described by a potential that evolves with temperature, developing a new minimum.

- For $T = T_c$ the new minimum and the former one are degenerated.

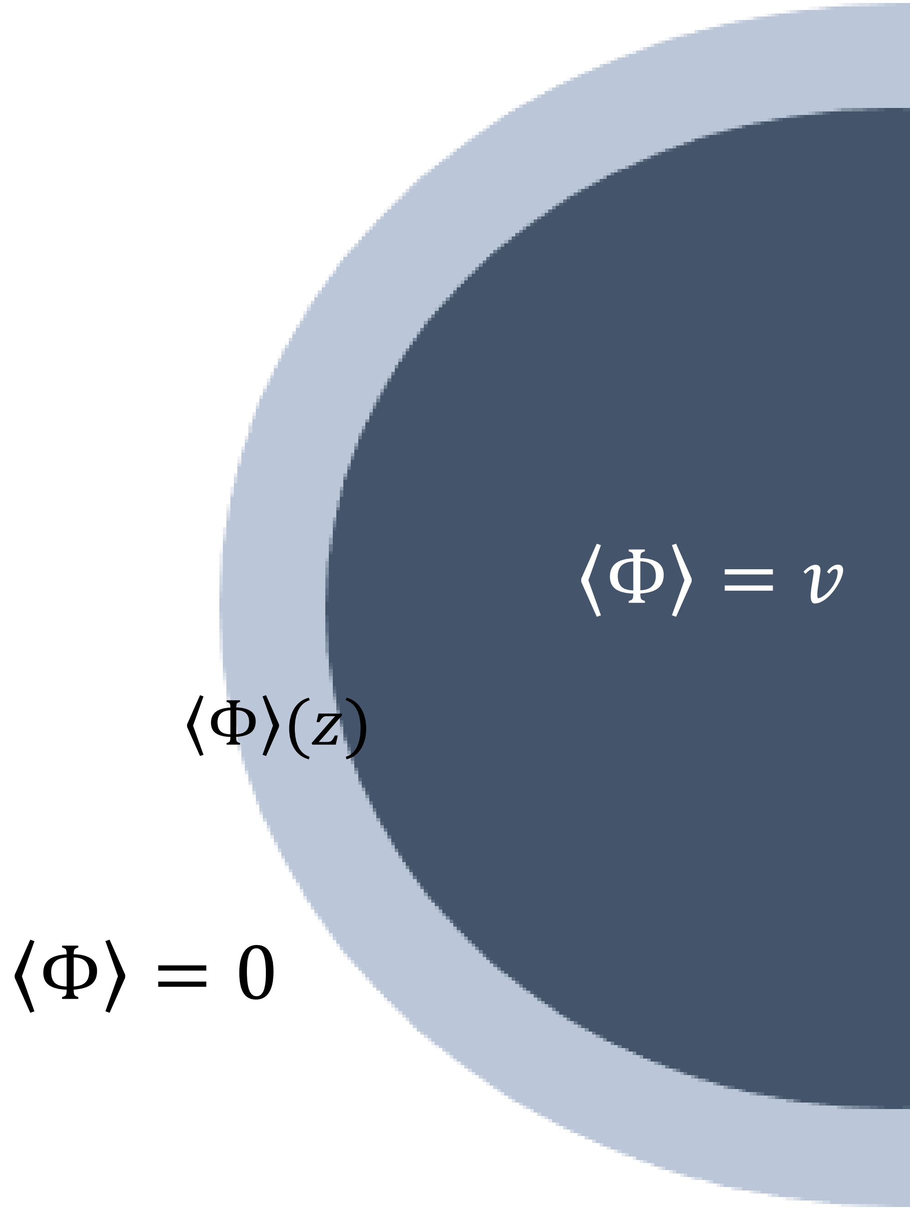
- For $T < T_c$ the new minimum is the global minimum. The transition is the change from the “false vacuum” to the “true vacuum”.



First-Order Phase Transitions

Bubbles

- The transition does not occur simultaneously. The regions where the transition has occurred form bubbles.
- The phase transition begins when these bubbles expand rather than collapse, $\rightarrow T_n$.
- The wall of the bubbles expand at velocity $v_w, \gamma_w = 1/\sqrt{1 - v_w^2}$.
- The expansion and collision of the bubbles give rise to a spectrum of gravitational waves.



The Bubble Expansion Mechanism

Dark Matter production

- Production of particles during the expansion of the bubbles:

  - $\Phi = h + \langle\Phi\rangle$ and φ are coupled
  - In the wall frame , the h particles hit the wall at v_w velocity
  - Lack of momentum conservation in the direction of expansion

  → $h \to \varphi\,\varphi$

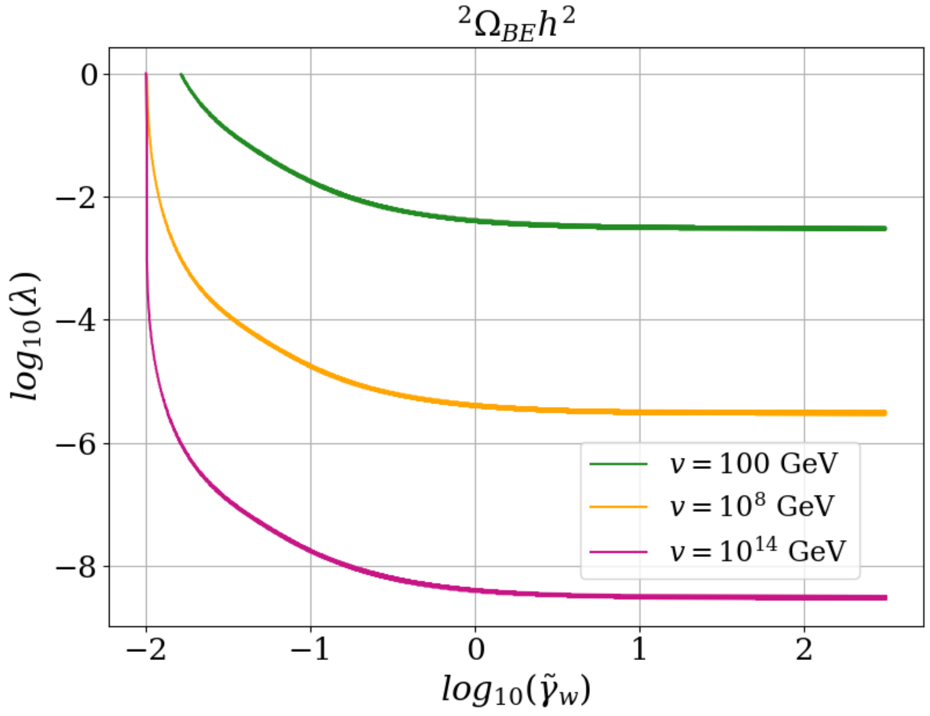
- For scalar particles:

$$L = \partial_\mu \Phi \partial^\mu \Phi^\dagger + \frac{(\partial\varphi)^2}{2} - \frac{M^2\varphi^2}{2} - \lambda\frac{\Phi^2\varphi^2}{2} - V(\Phi) \longrightarrow L_{int} = \lambda\langle\Phi\rangle h\varphi^2$$

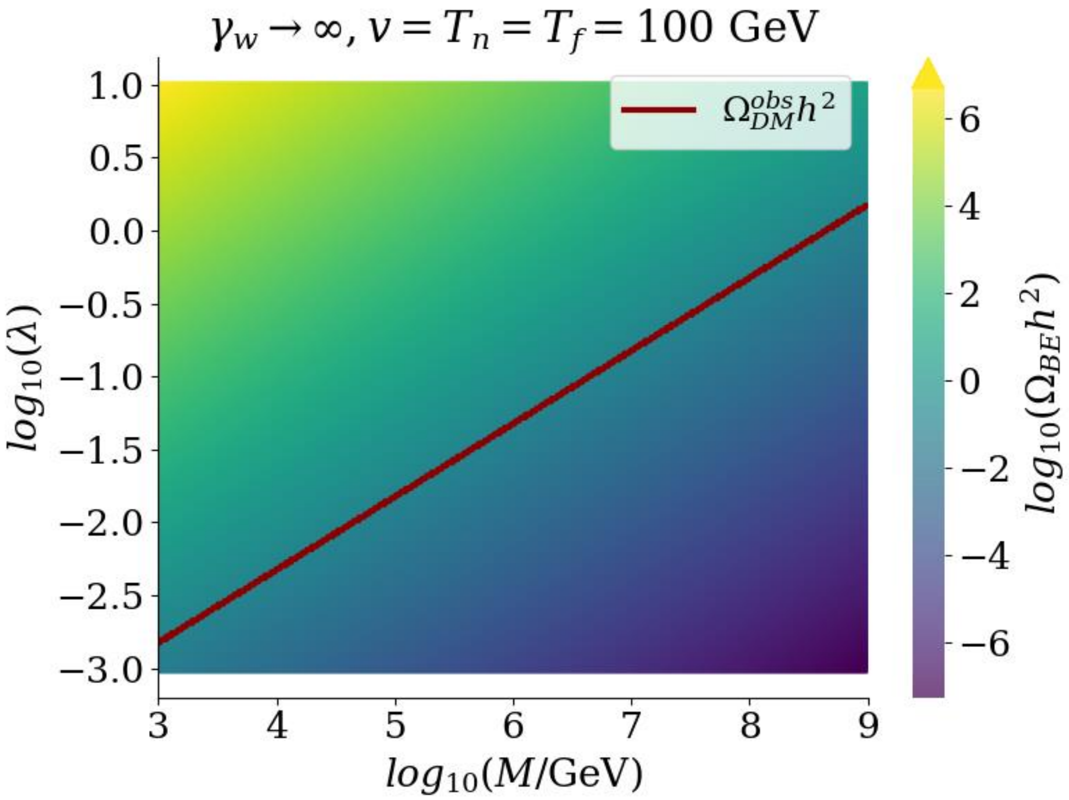
Results

Parameter space

- $\tilde{\gamma}_w \equiv \gamma_w \frac{vT_n}{M^2}$ $\Omega_{DM}h^2 = 0.12$



$$\frac{vT_n}{M^2} = 0.01; \tilde{\gamma}_w \geq 0.01$$



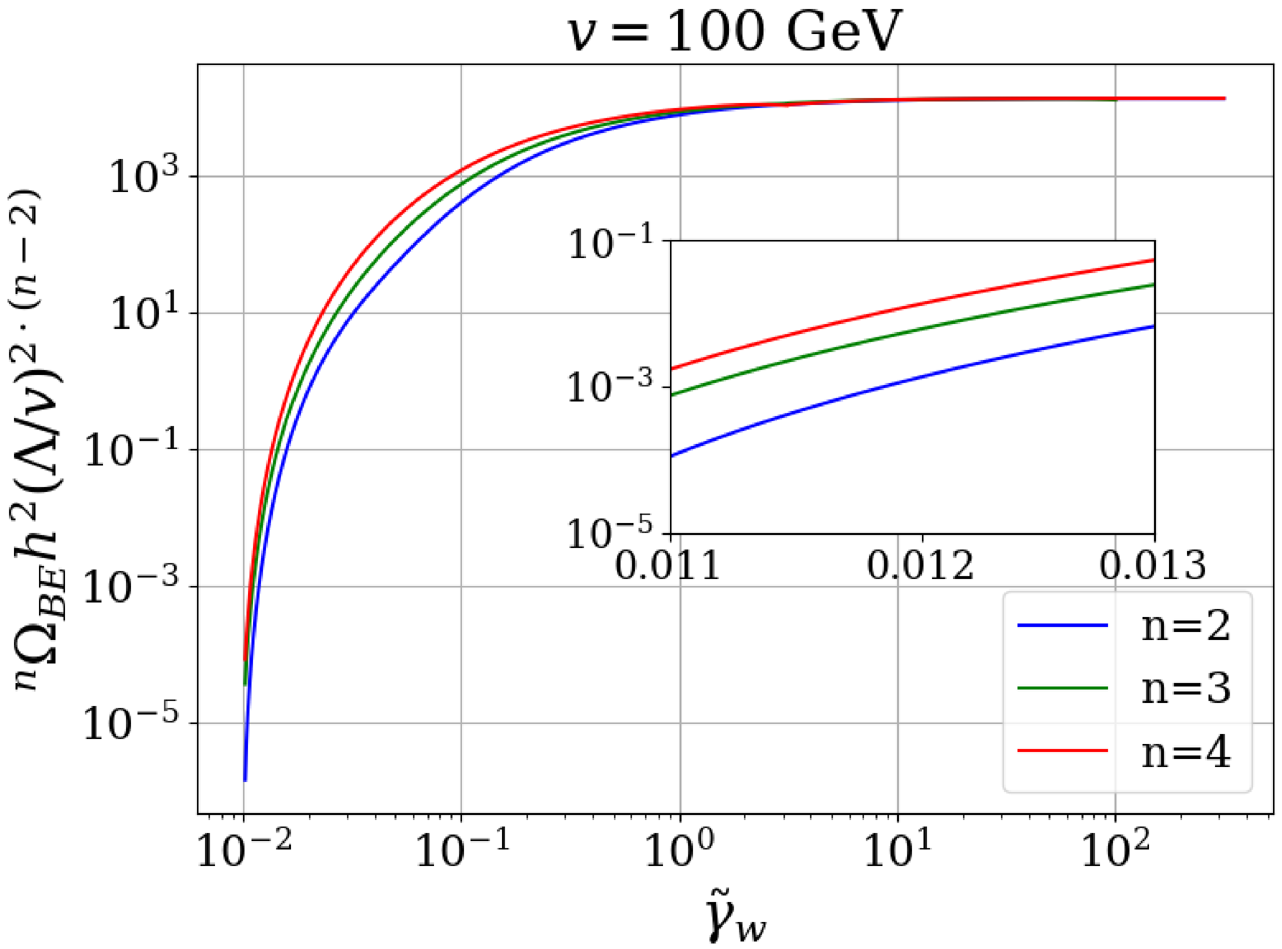
Results

Analytical approximation and other cases

- More general interactions have been considered

$$L_{int} = \lambda \frac{\langle \Phi \rangle^{n-2}}{\Lambda^{n-2}} \langle \Phi \rangle h \varphi^2$$

$$\frac{v^{n-2}}{\Lambda^{n-2}}$$



Conclusions

- First-Order Phase Transitions could play a role in the production of Dark Matter
- The Bubble Expansion mechanism allows for a Dark Matter production in agreement with the observational value
- The studied mechanism does not require a specific regime of the Lorentz factor of the wall
- The Bubble Expansion allows a range of masses of the dark matter candidate typically forbidden in other mechanisms