

# Black holes and gravitational waves from slow first-order phase transitions

Piotr Toczek,

Faculty of Physics, University of Warsaw

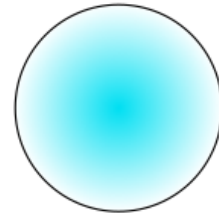
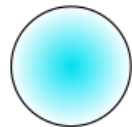
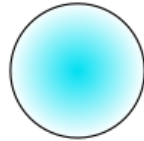
in collaboration with  
Marek Lewicki and Ville Vaskonen

*"old" phase*

*"old" phase*

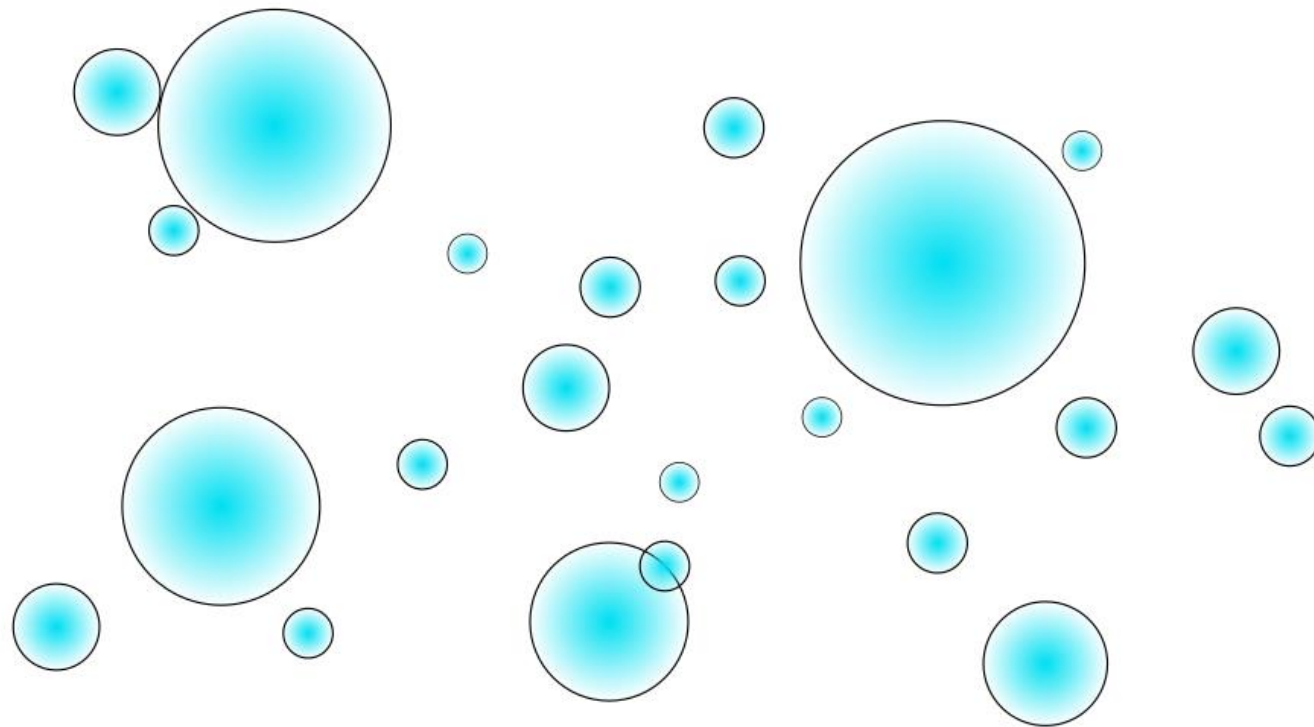
*"new" phase*

$$\Gamma(t) = H_I^4 e^{\beta t}$$



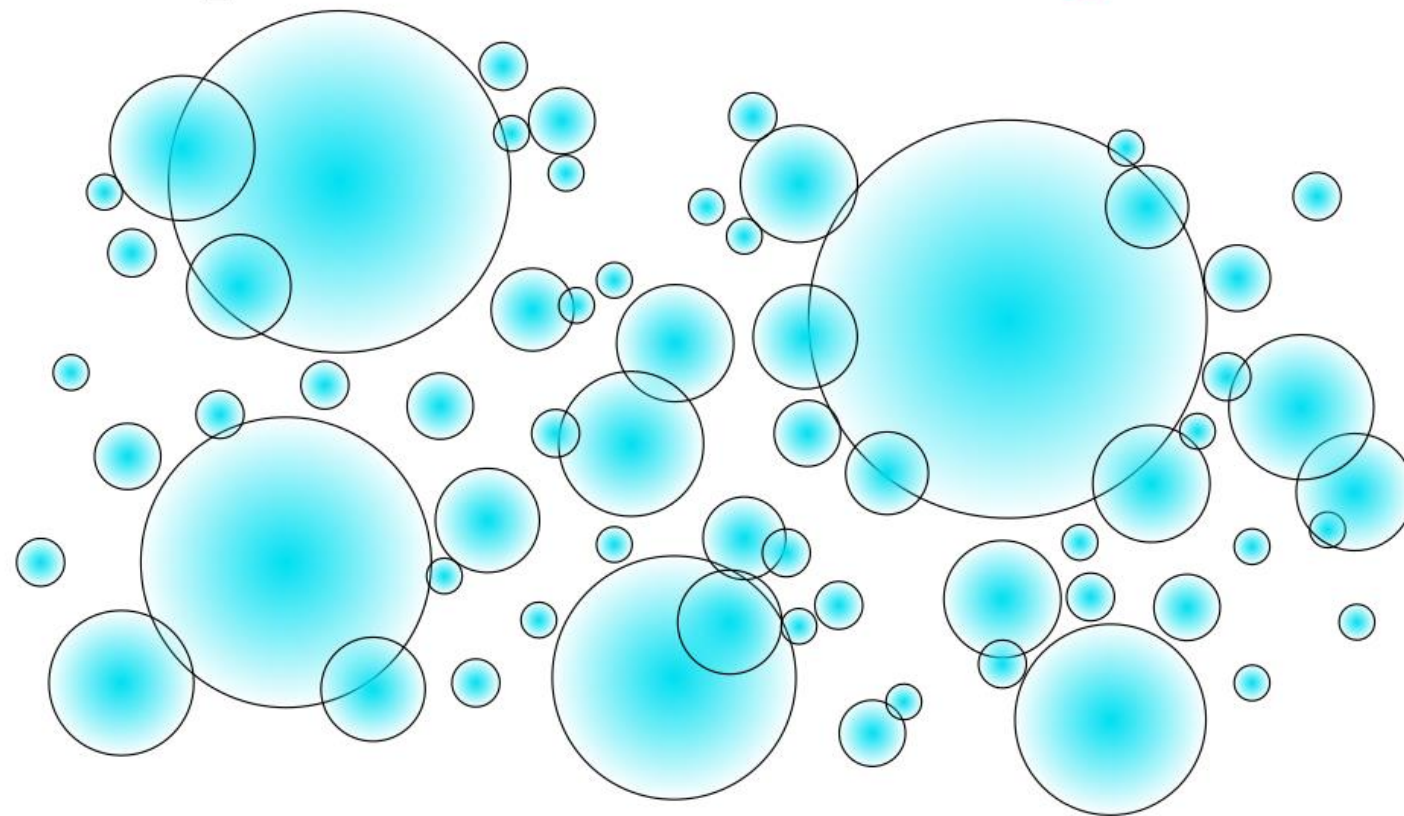
*"old" phase*

*"new" phase*



*"old" phase*

*"new" phase*



# BLACK HOLE FORMATION

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Statistical nature of bubble  
nucleation  
↓  
inhomogeneities

Slow, supercooled transition  
↓  
period of thermal inflation

# BLACK HOLE FORMATION

Statistical nature of bubble  
nucleation



inhomogeneities

Slow, supercooled transition



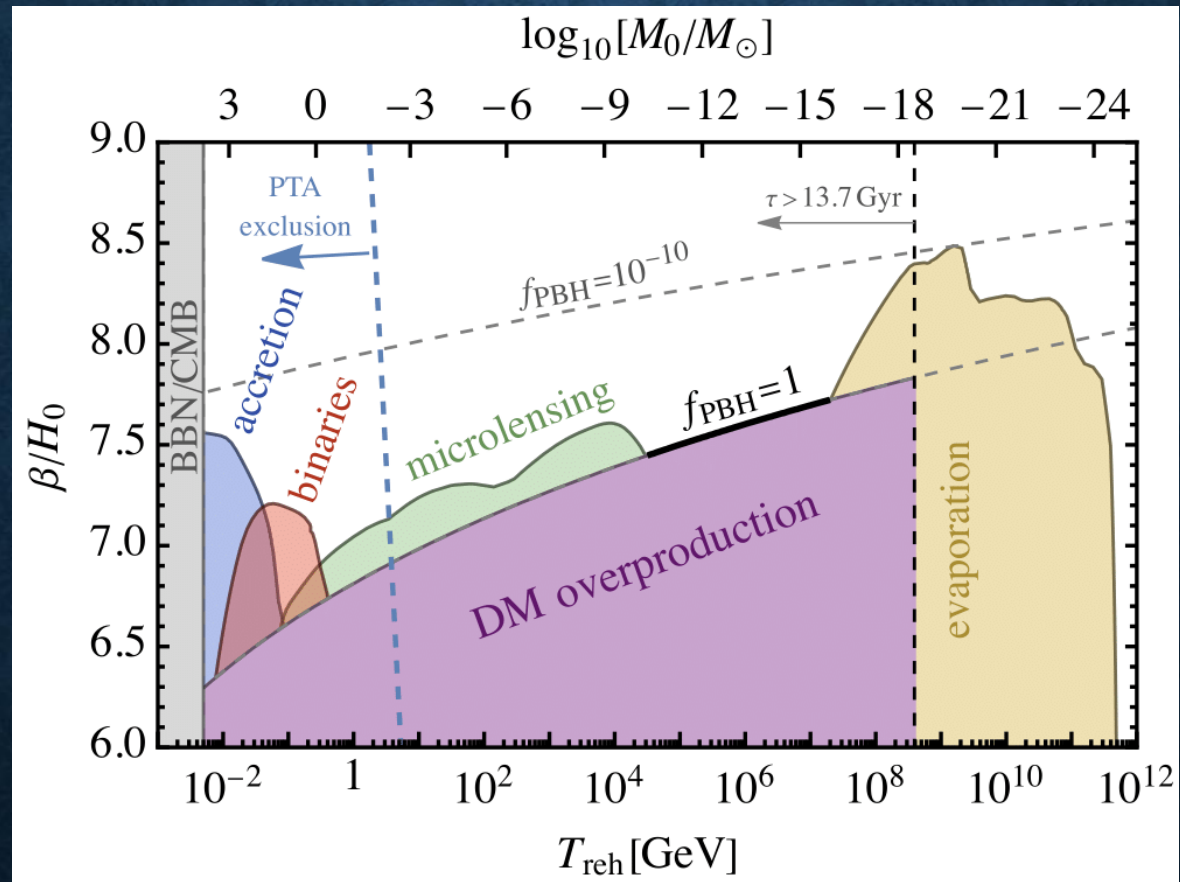
period of thermal inflation

$$\dot{\rho}_r + 4H\rho_r = -\dot{\rho}_v$$

Large fluctuations of  
energy density

$$\delta = \frac{\rho - \rho_b}{\rho_b}$$

# BLACK HOLE FORMATION

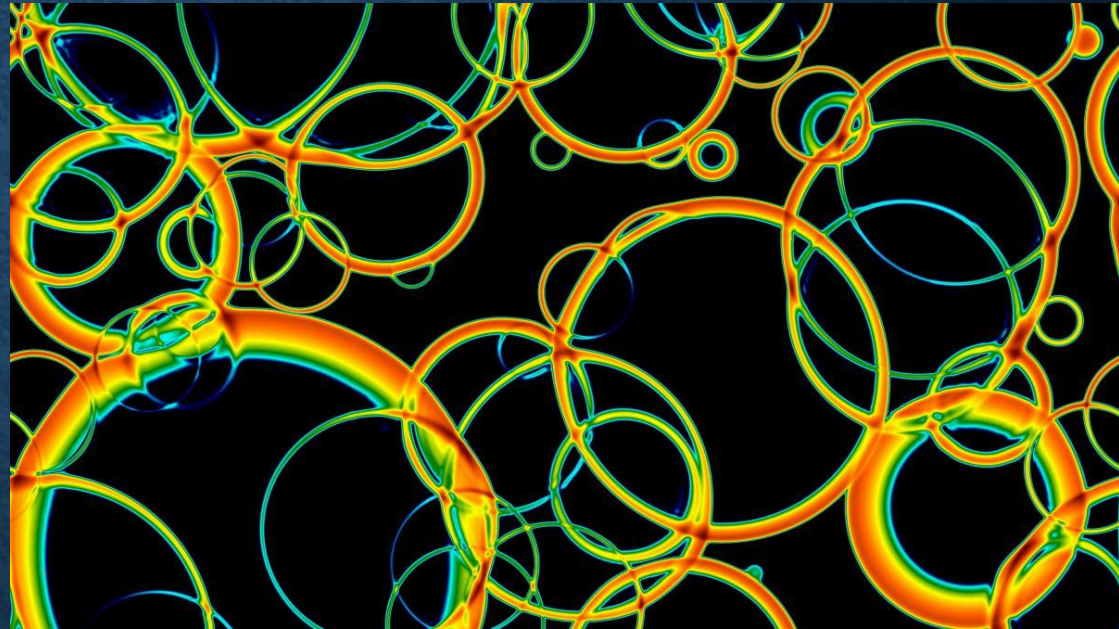




# GRAVITATIONAL WAVES

During phase transition:

- bubble collisions
- sound waves in plasma



D. Weir, University of Helsinki

# GRAVITATIONAL WAVES

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During phase transition:

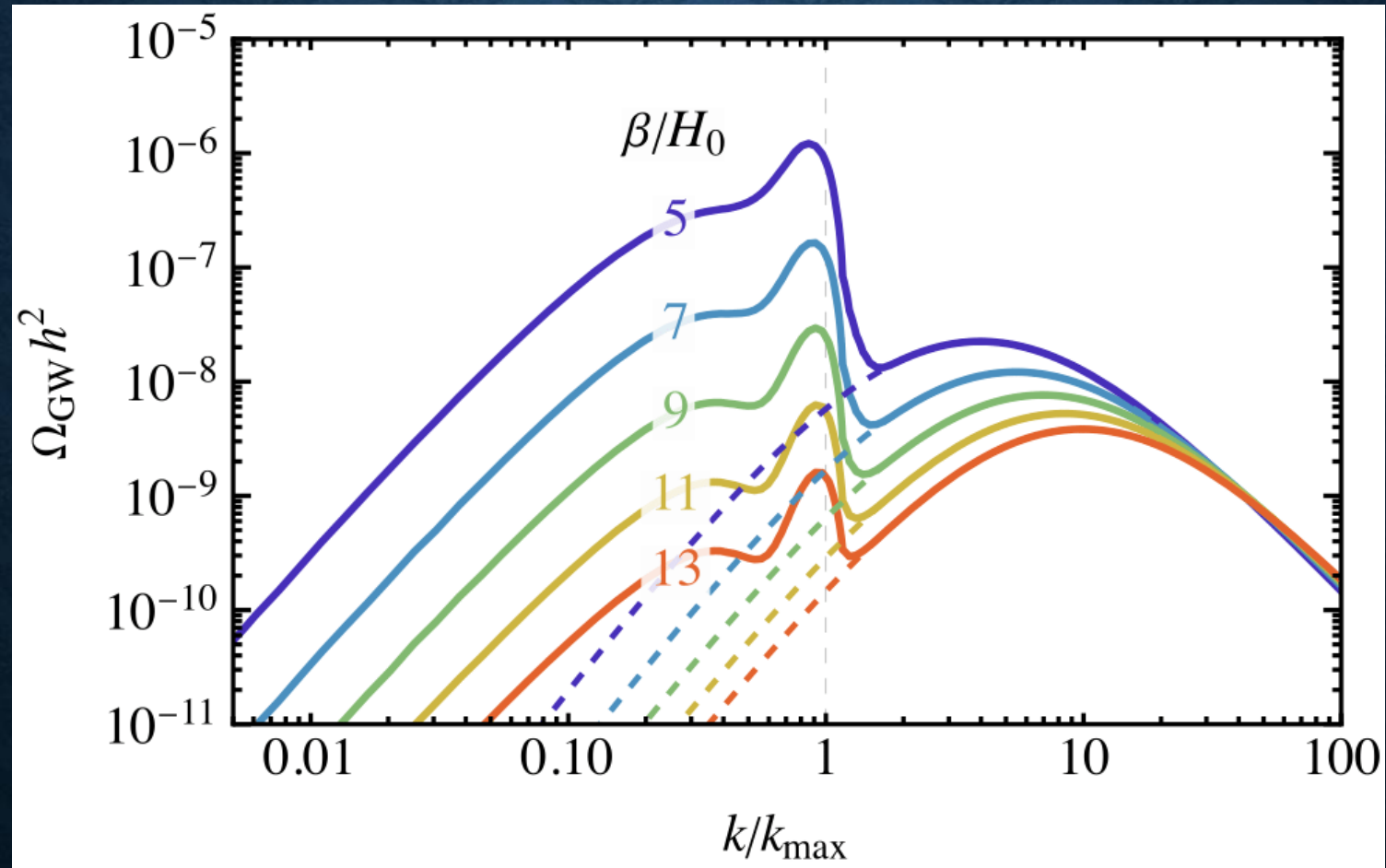
- bubble collisions
- sound waves in plasma

Second order effects?

- scalar induced gravitational waves

Energy density  
fluctuations  GWs

# GRAVITATIONAL WAVES



Thank you!