EuCAPT 22

Effect of density fluctuations on gravitational wave production in first-order phase transitions

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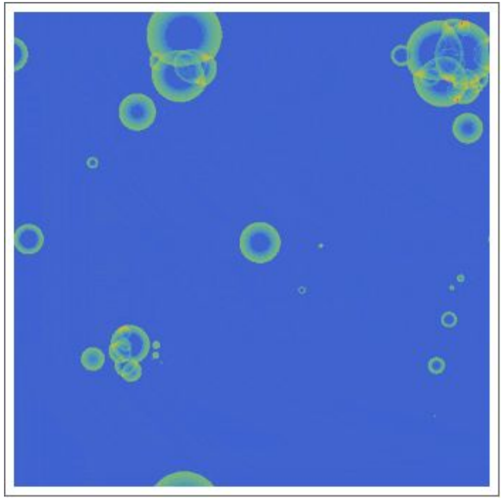
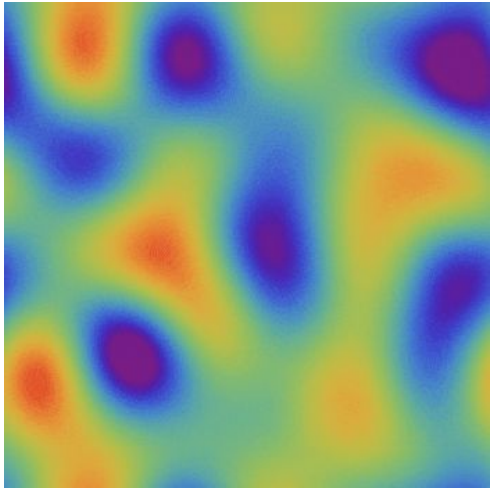
2108.11947 JCAP

Before anything, the most important... Cool stuff always come with videos





The message to take home...

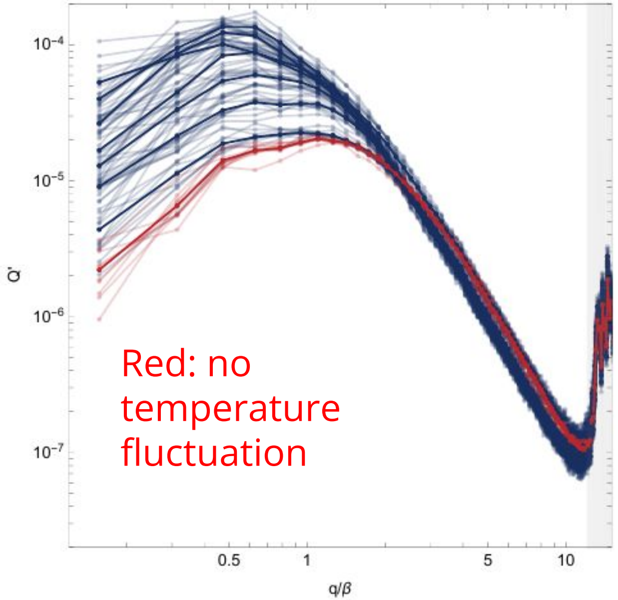
Gravitational waves from first order phase transitions are affected by temperature fluctuations on scales

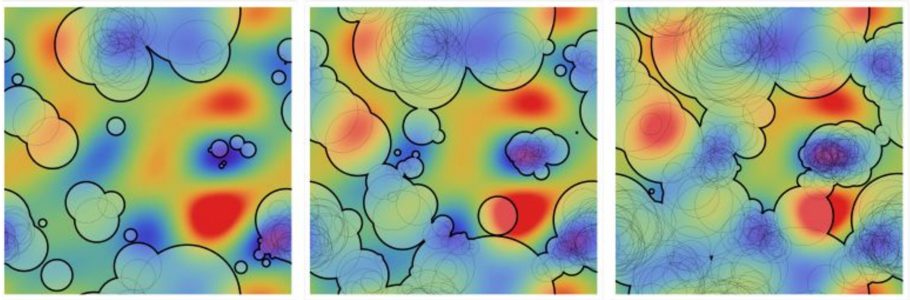
$$H_* < k_* < \beta$$

In order to see this effect, we need the enhancement in temperature fluctuations to be

$$\mathcal{P}_\zeta(k_*) \gtrsim (\beta/H_*)^{-2}$$

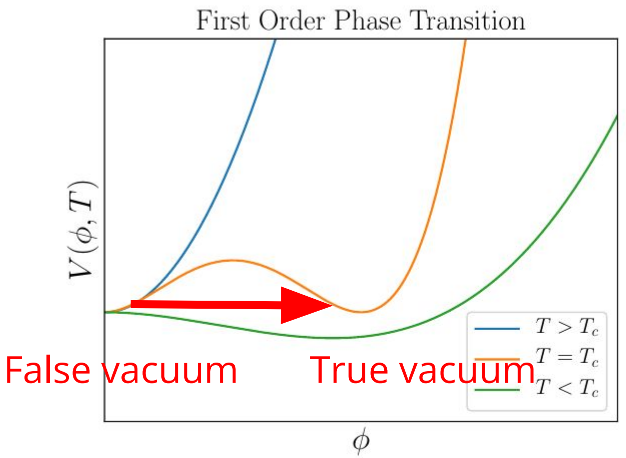
Since $\beta/H_* \sim \mathcal{O}(100 - 1000)$ we don't need such large temperature fluctuation to see this effect





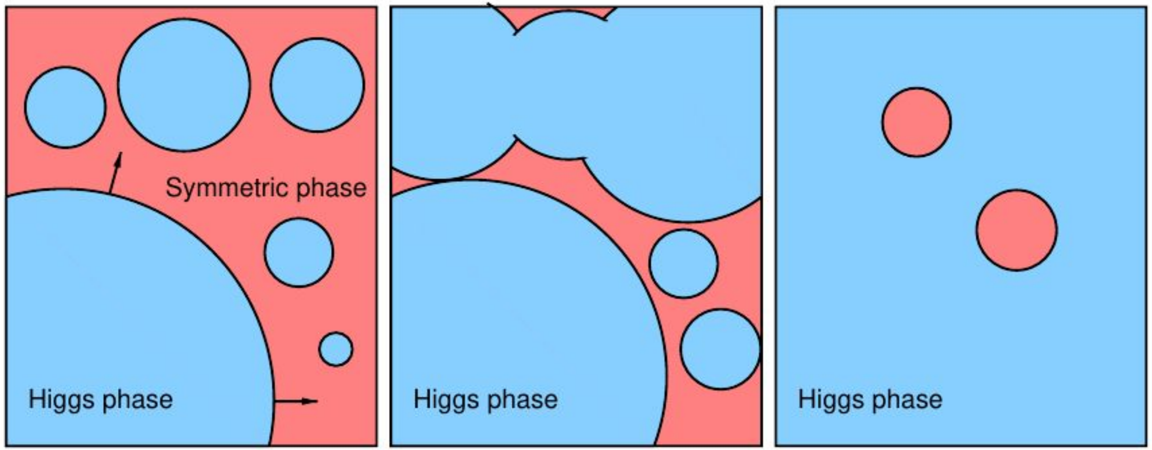
1st Order Phase Transition (PT)

Henrique Rubira



$$\Gamma(t) = \Gamma_* e^{\beta(t-t_*)}$$

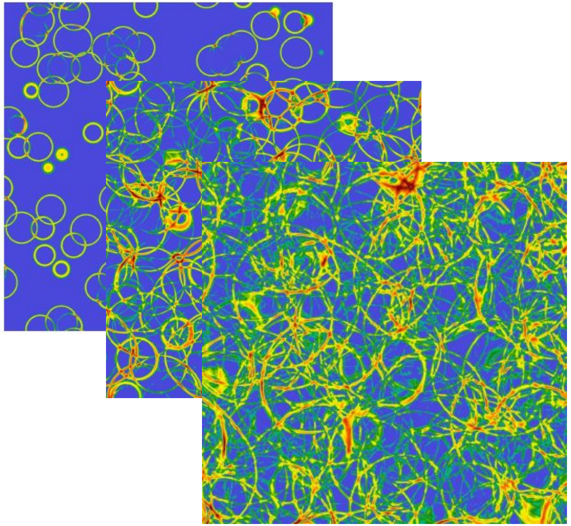
Disjoint regions of space can make the transition, generating bubbles at different places



For a review, see Maggiore's book or (Hindmarsh, Lüben, Lumma, Pauly 20)

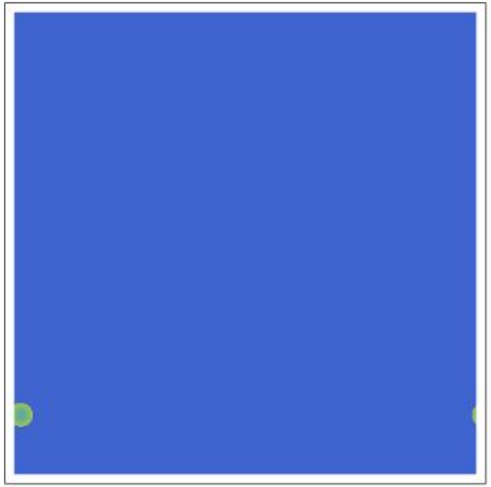
GW from 1st Order PT -- Lattice simulations

Fluid + Scalar



Hindmarsh, Huber,
Rummukainen, Weir
(13,15,17) + Cutting (19)

Hybrid: hydro 1d + with Higgs field included as a boundary condition



Jinno, Konstandin,
Rubira (20)

Is it the end of the story connecting observed spectra to sourced spectra?

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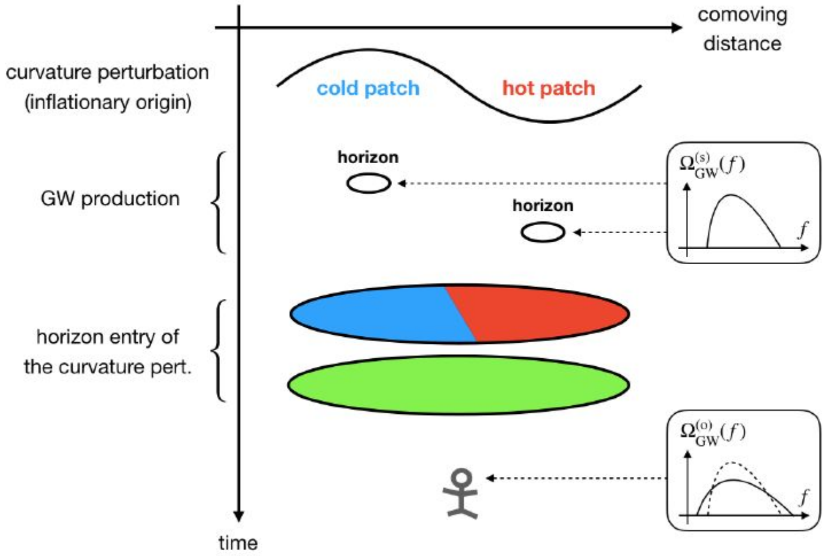
We know that temperature fluctuations in the line-of-sight can affect the GW spectrum

Domcke, Jinno and **Rubira** 2002.11083



Similar to (I)SW for CMB

Can temperature fluctuations also affect the sourcing of GWs from 1st order PTs?

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Henrique Rubira

Nucleation rate proportional to the 3d bounce action: $\Gamma \propto e^{-S_3/T}$

After expanding it around $t = t_*$

$$\Gamma = \Gamma_* \exp\left[\beta(t - t_*) - \frac{\beta}{H_*}\frac{\delta T}{\overline{T}}\right]$$

This next term in the expansion may be large if $\frac{\delta T}{T} \sim \left(\frac{\beta}{H_*}\right)^{-1}$

Henrique Rubira

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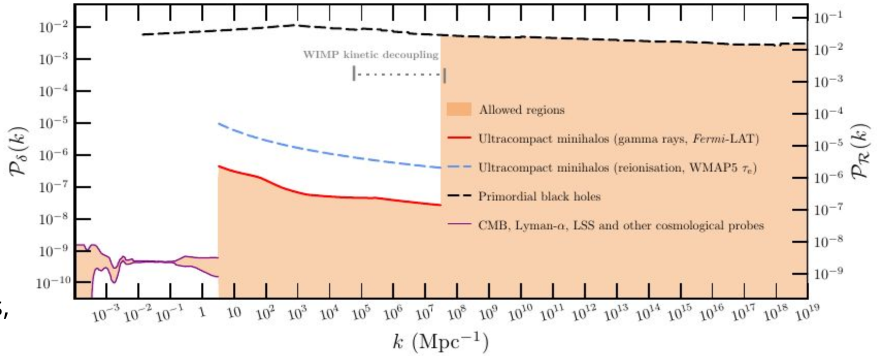
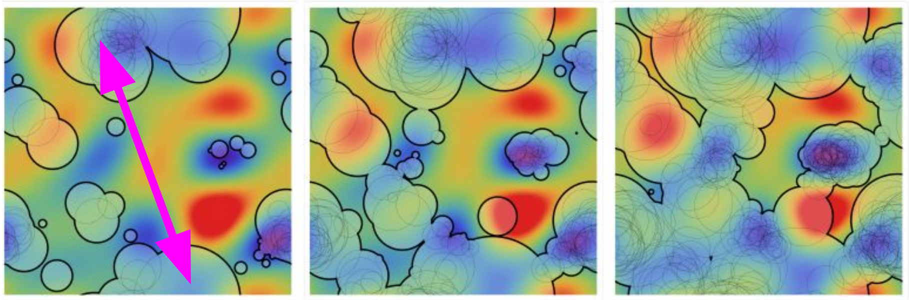
Since we are talking about T~Tev, it is pretty in the (unconstrained) UV



Bringmann, Scott, Akrami, 1110.2484. See also Byrnes, Cole, Patil

What is the effect in the GW spectra?

We simulate bubble nucleation under temperature fluctuations and plug it into the hybrid simulation



Result: increase the bubbles size and therefore enhance GW spectra

Henrique Rubira

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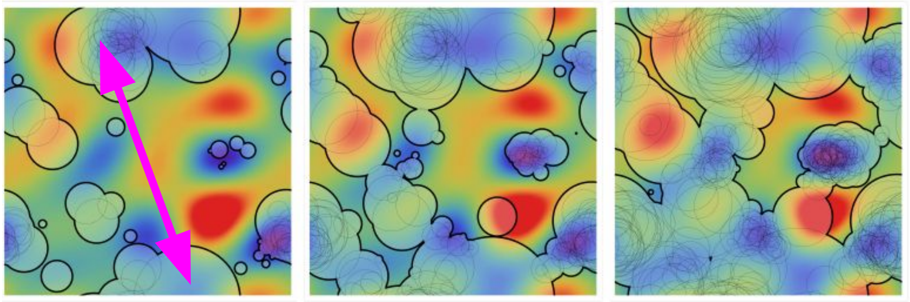

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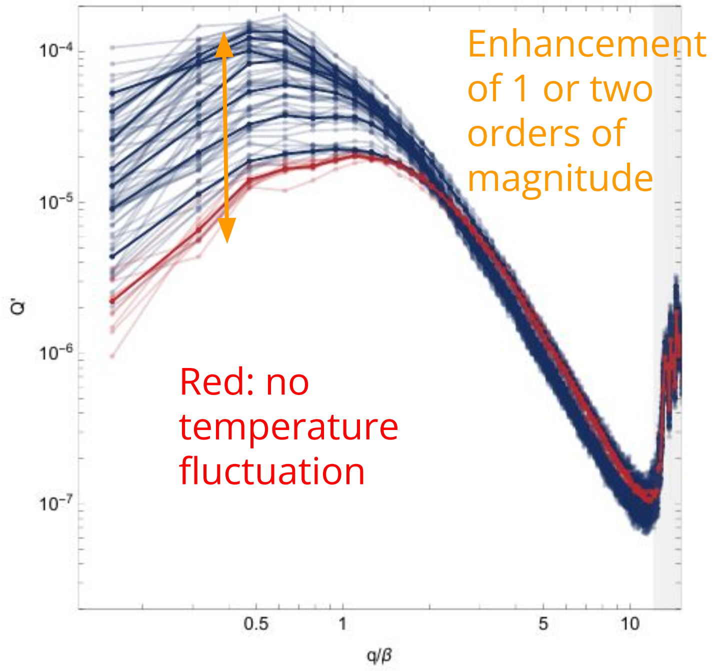


We also parametrized how spectra depends on temperature fluctuations

Conclusions

GWs may also unveil information about fluctuations in the background fluid.

Enhancement of GW spectra by one or two orders of magnitude may be taken into account, increasing expectations to detect GW.

The scale of this enhancement if parametrized in terms of the scale of temperature fluctuations.

We don't need such a big enhancement of temperature fluctuations to see this effect

$$\mathcal{P}_\zeta(k_*) \gtrsim (\beta/H_*)^{-2} \quad \text{with} \quad \beta/H_* \sim \mathcal{O}(100 - 1000)$$

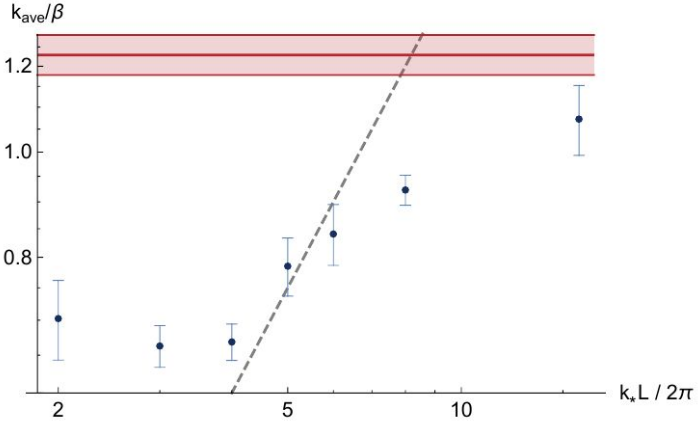
Thanks a lot!

Henrique Rubira

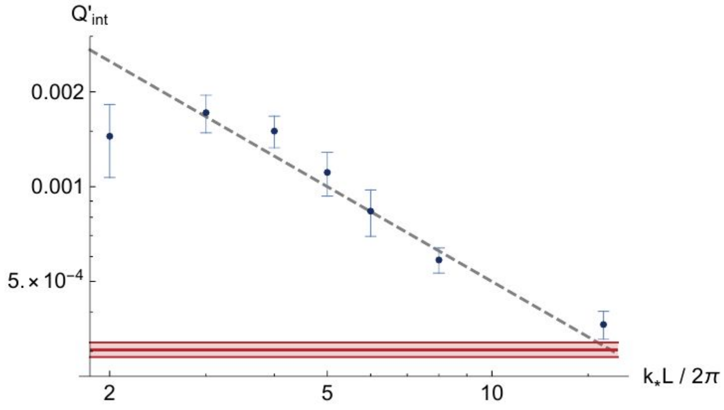
Extra slide: parametrizing the spectra

$$k_{\rm ave} \equiv \int d\ln k \; k \; Q'(k) \Big/ \int d\ln k \; Q'(k),$$

$$Q'_{\rm int} \equiv \int d\ln k \; Q'(k).$$



Red: no temperature fluctuation



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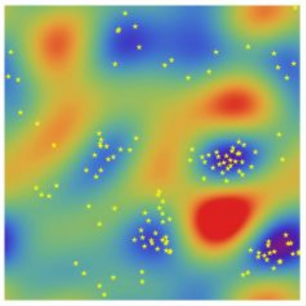
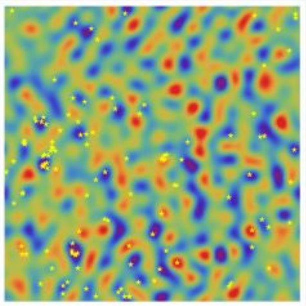
Extra slide: deep IR, IR and UV

Deep IR: temperature is uniform, no difference



Only IR affects the spectra



In the limit in which $k_* \to \infty$, it does not affect the spectra since any volume has many hot and cold spots

Extra slide: the algorithm

Henrique Rubira

Instead of letting bubbles nucleate linearly distributed in space and (exp) time, we consider the cumulative probability calculated from the Temperature grid