

# Thermal fluctuations of the composition in quark nucleation

**Mirco Guerrini**

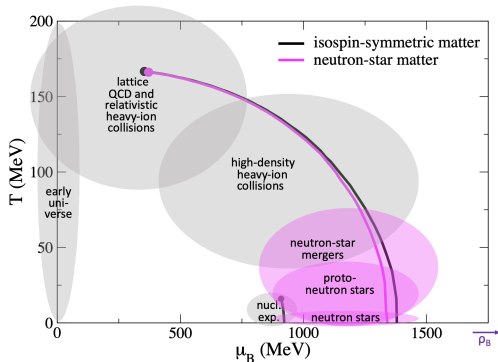
collaborators: A. Drago (UniFe), G. Pagliara (UniFe) and A. Lavagno (PoliTo)

Sesto Incontro Nazionale di Fisica Nucleare



**Università  
degli Studi  
di Ferrara**

# Deconfinement in astrophysical systems



**Quarks** d.o.f. expected at  $n_B \gg n_0$

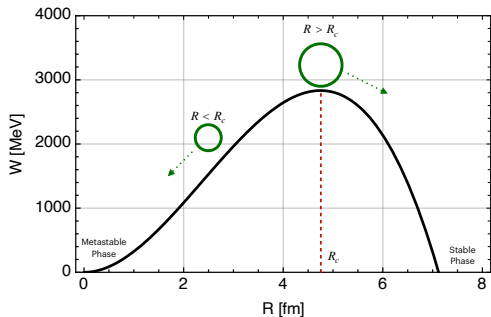
Extreme densities reached in astrophysical phenomena related to **compact objects**

**Deconfinement** could play a key role in astrophysical phenomena (e.g. BSGs CCSNe, see Fischer et al. 2018)

|                                 | $n_B/n_0$ | $T$ [MeV] | $Y_e$ |
|---------------------------------|-----------|-----------|-------|
| Isolated NS                     | $10^8$    | 8         | 0     |
| Core Collapse Supernovae (CCSN) | $10^8$    | 8         | 0 50  |
| Proto NS (PNS)                  | $10^8$    | 8         | 0 50  |
| Binary NS Mergers (BNSM)        | $10^8$    | 8         | 0 100 |

# Nucleation: the first seed of a new stable phase

if  $H(P_H) > Q(P_Q)$   $H$  is a **metastable phase** ) virtual drops of  $Q$  created



$$W(P; T) = \frac{4}{3} R^3 n_B^Q [Q - H] + 4 \pi R^2$$

Thermal :  $P_{th} \sim e^{-\frac{W(R_c)}{T}}$   
 (Langer et al. 1969 and Landau et al. 1980)

Quantum :  $P_q \sim e^{-\frac{A(E_0)}{\hbar}}$   
 (Iida et al. 1998)

**Formation of the first critical quark seed ) deconfinement**

# Method

## State of the art (*Bombaci et al. 2016*)

weak processes are too slow

avour composition is **frozen**

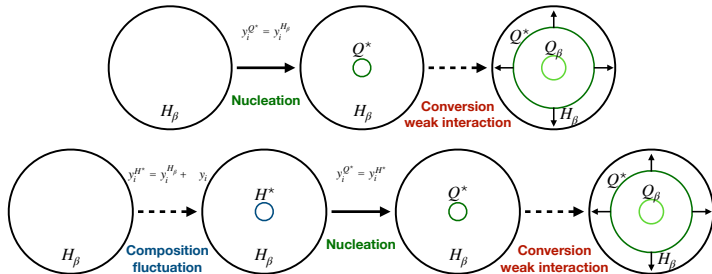
$$P(P; T) = P_{nuc}^{H_\beta \rightarrow Q^*}$$

## Our approach (*Guerrini et al. 2024*)

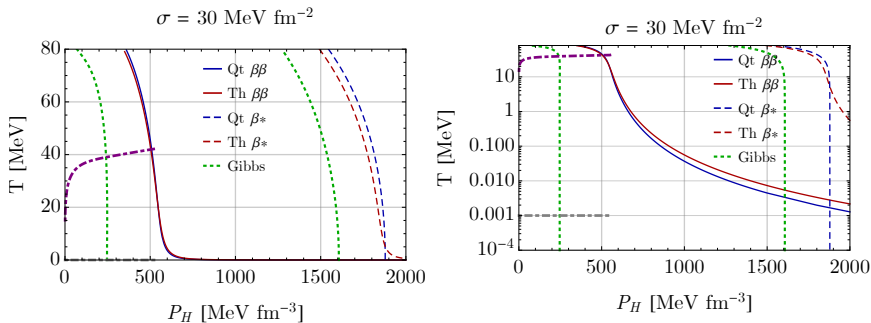
at  $T \neq 0$  hadronic composition **fluctuates**

around the average values  $\langle y_i^{H_\beta} \rangle$

$$P(P; T; y_i) = P_{nuc}^{H^* \rightarrow Q^*} P_{uc}^{H_\beta \rightarrow H^*}$$



# Application to two flavour case



( ) :  $y_i = 0$  ; ( ) :  $y_i$  such that  $y_i^H = y_i^Q$   
 $P; T$  such that nucleation time  $\approx 1 \text{ s}$

fluctuations of the hadronic composition:

small T: fluctuations role negligible

high T: nucleation starts at a much lower pressure

# Summary

## Introduction

exotic degrees of freedom expected at compact object densities  
nucleation is the starting point for the deconfinement process

## State of the art

flavour composition frozen during nucleation (*Bombaci et al. 2016*)

## Method

at finite  $T$  hadronic composition fluctuates around  $y_i^H$   
one more step: I. Fluctuation in hadronic composition, II. Nucleation

## Results

nucleation starts at a much smaller pressure at high-intermediate  $T$

## Outlooks

Application to three flavours

Conversion process of hadronic to quark matter

Search observables for the deconfinement (e.g. AT2018cow delayed signal wrt SN)