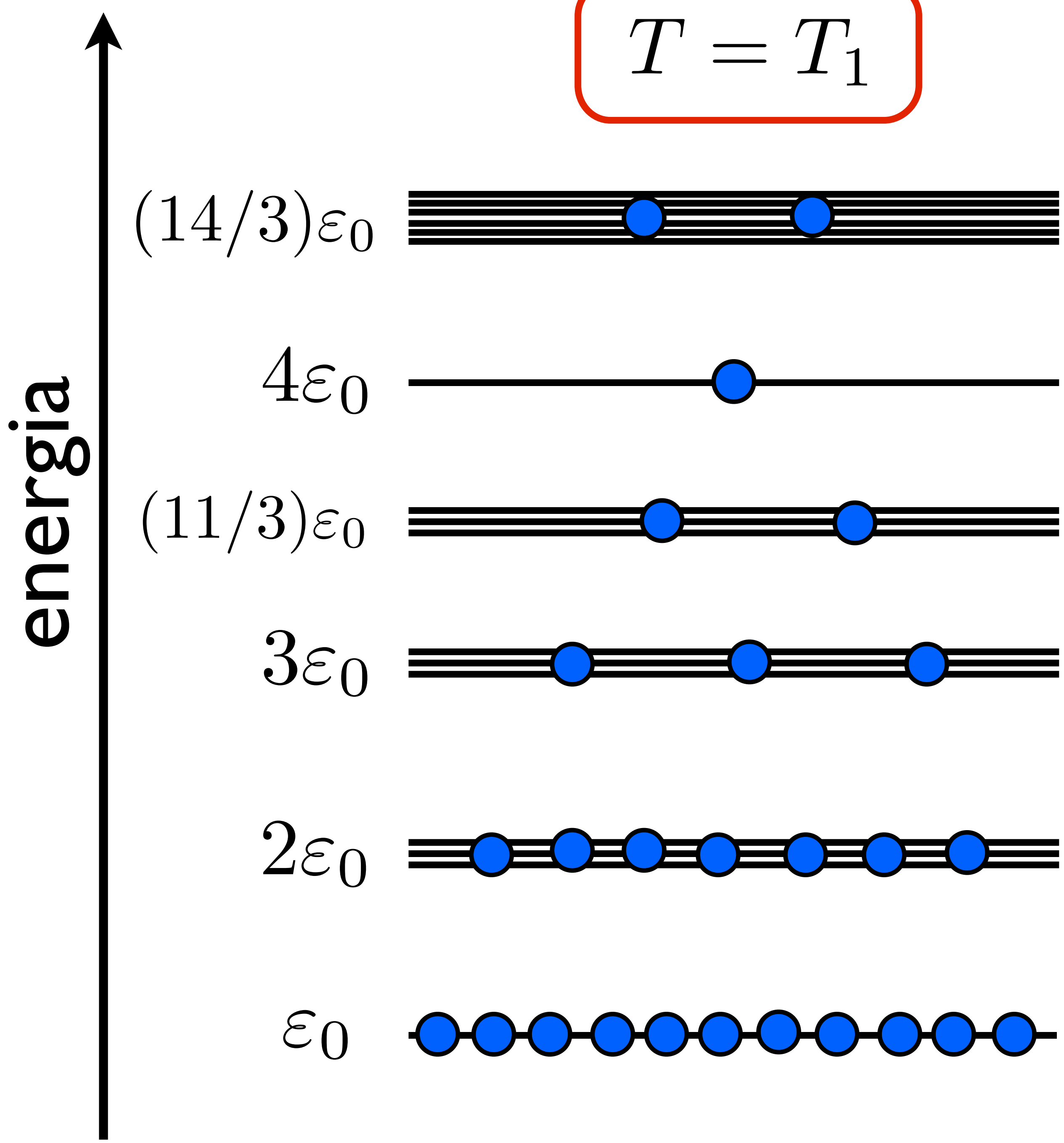
Ocupação dos níveis de energia

$T = T_1$



$N = 20$

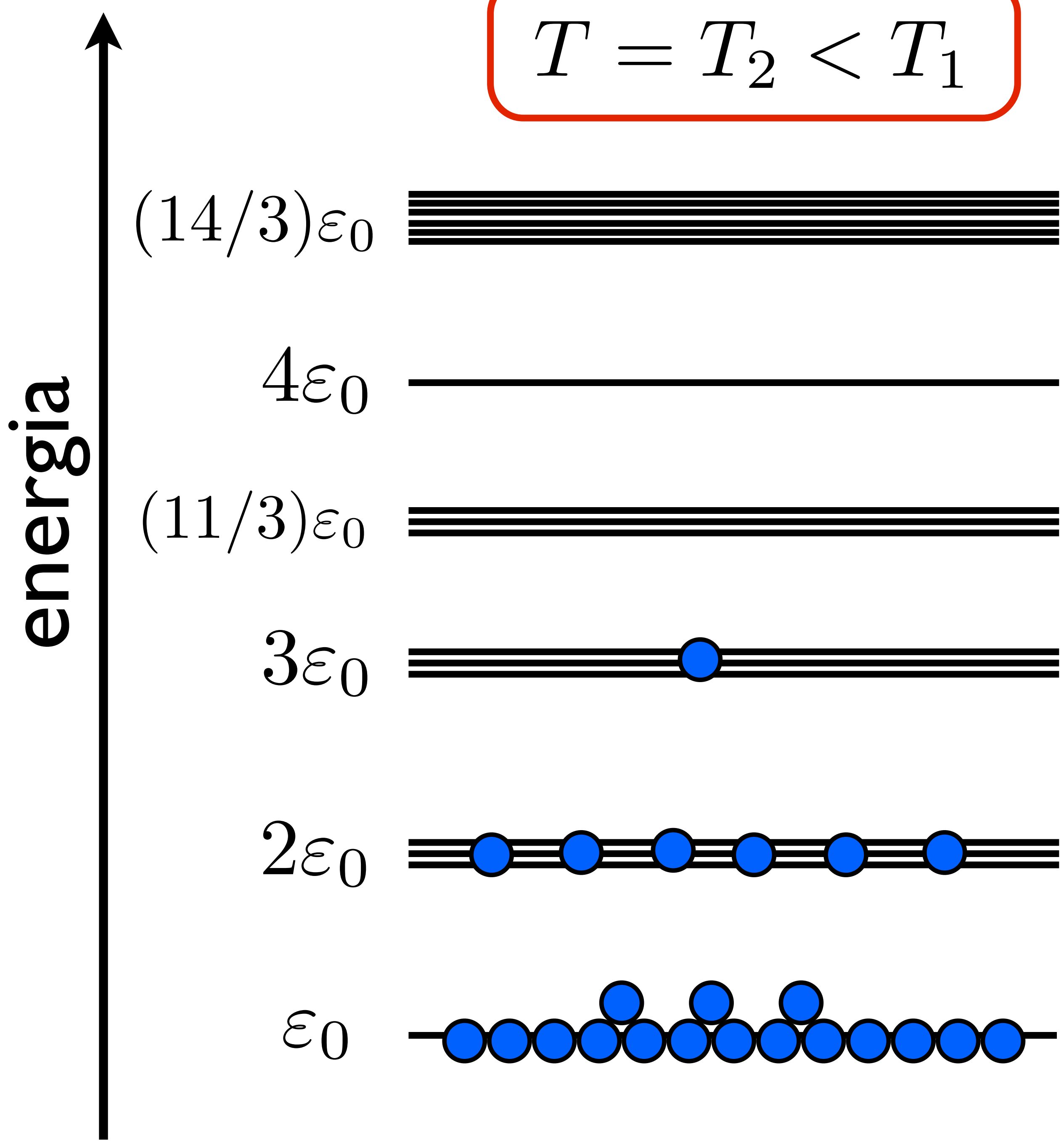
$$\varepsilon = \varepsilon_0 \frac{n_x^2 + n_y^2 + n_z^2}{3}$$

$$\varepsilon_0 = \frac{\hbar^2 \pi^2}{2mL^2}$$

$$n_x, n_y, n_z = 1, 2, 3, \ldots$$

Ocupação dos níveis de energia

$$T = T_2 < T_1$$



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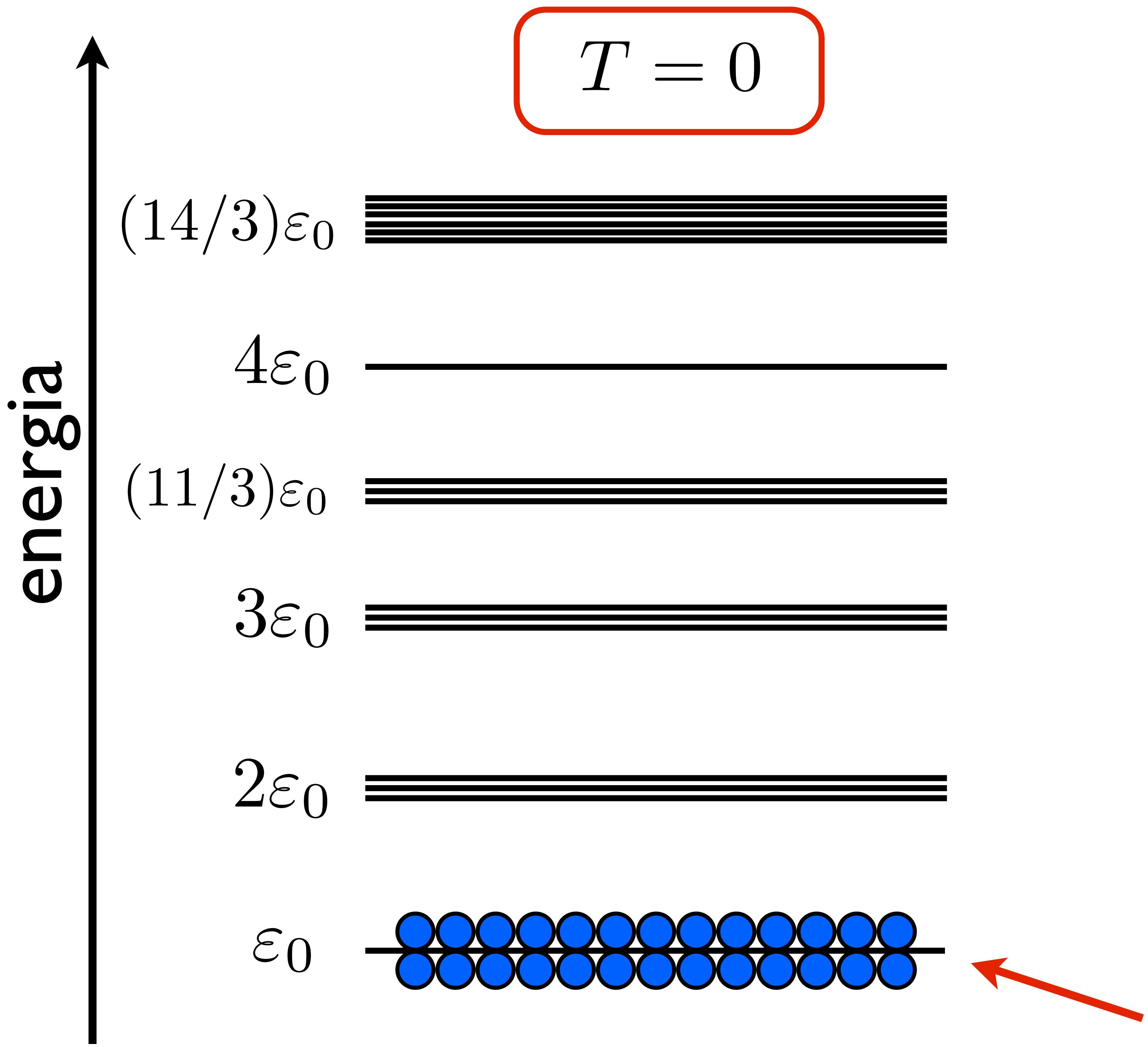
Ocupação dos níveis de energia



$N = 20$

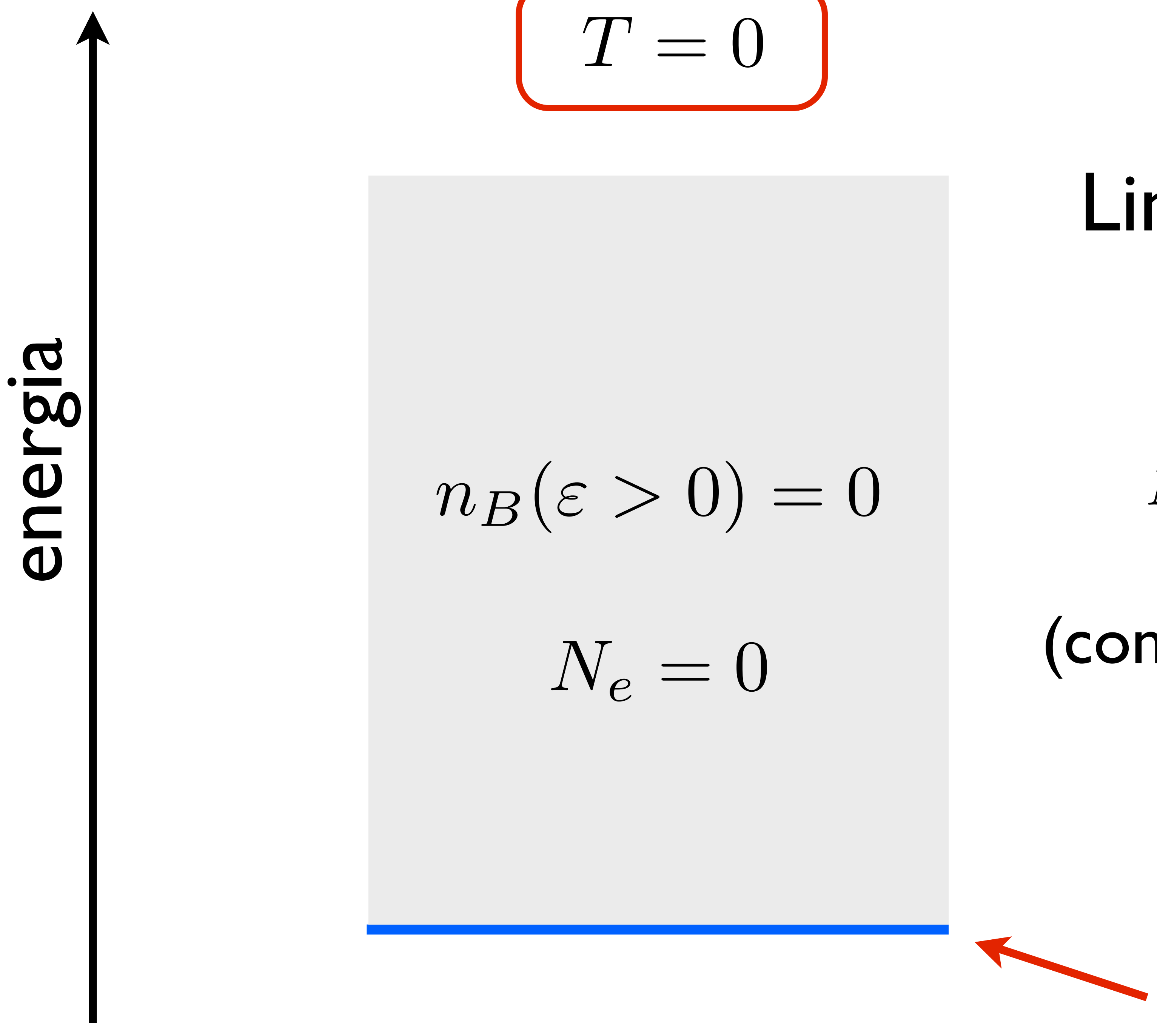
$$\varepsilon = \varepsilon_0 \frac{n_x^2 + n_y^2 + n_z^2}{3}$$

$$\varepsilon_0 = \frac{\hbar^2 \pi^2}{2mL^2}$$

$$n_x, n_y, n_z = 1, 2, 3, \ldots$$

Ocupação dos níveis de energia

$T = 0$



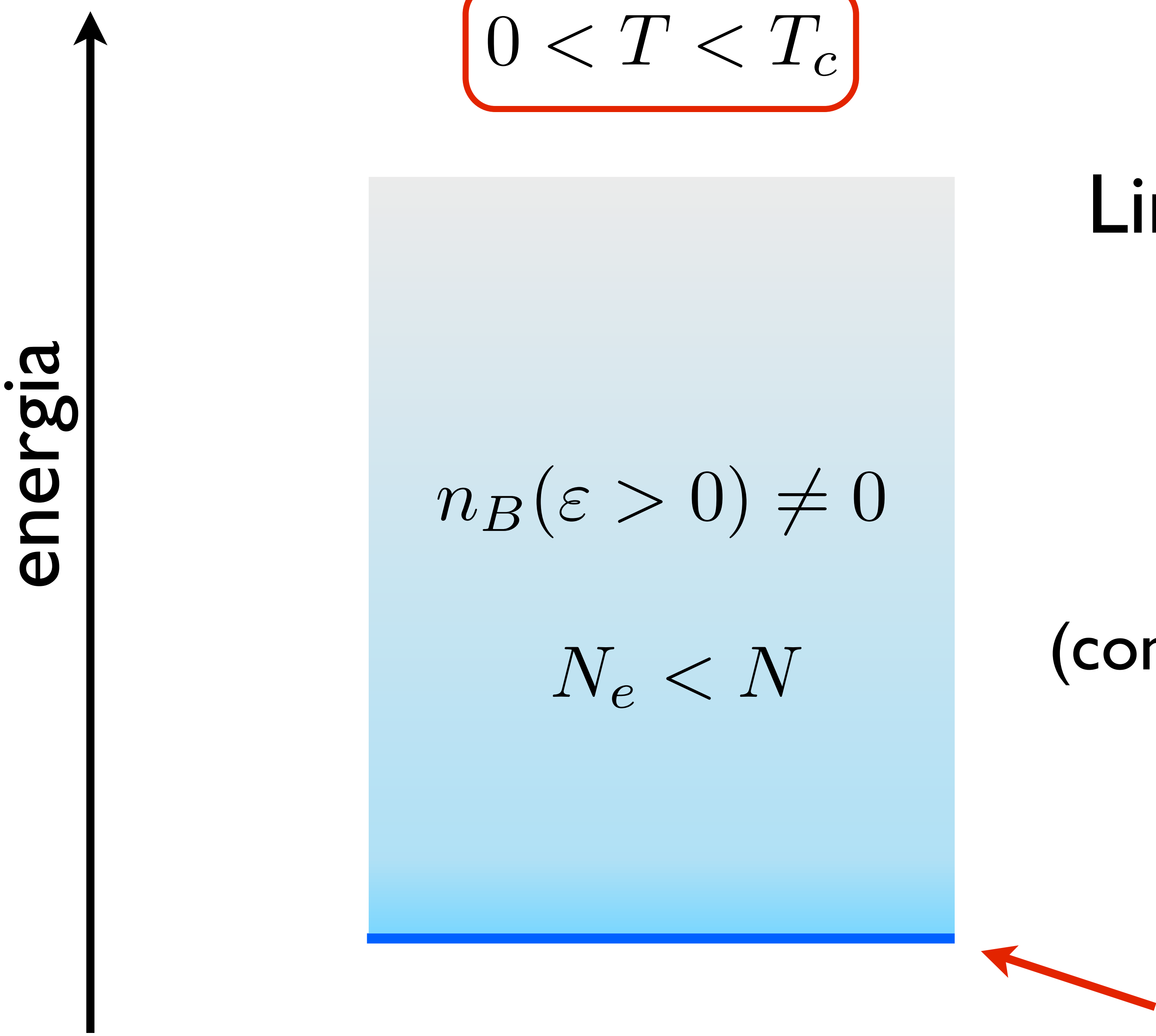
Limite termodinâmico:

$$\lim_{N,V\to\infty} \frac{N_0}{V} = \rho_0 > 0$$

(condensado de Bose-Einstein)

Ocupação dos níveis de energia

$0 < T < T_c$



$$n_B(\varepsilon > 0) \neq 0$$

$$N_e < N$$

$$N_0 > 0$$

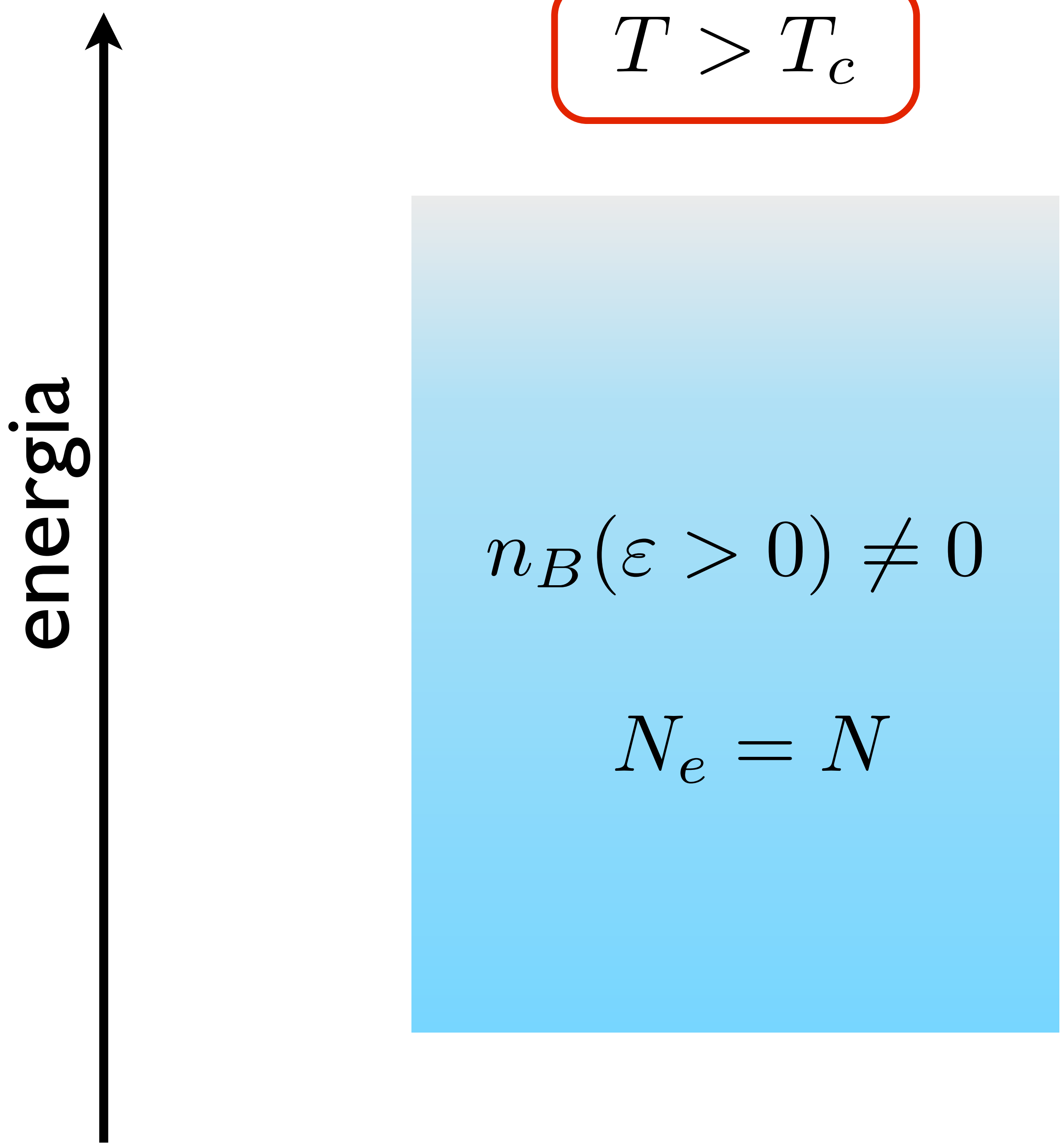
Limite termodinâmico:

$$\lim_{N,V \to \infty} \frac{N_0}{V} = \rho_0 > 0$$

(condensado de Bose-Einstein)

Ocupação dos níveis de energia

$T > T_c$



$$n_B(\varepsilon > 0) \neq 0$$

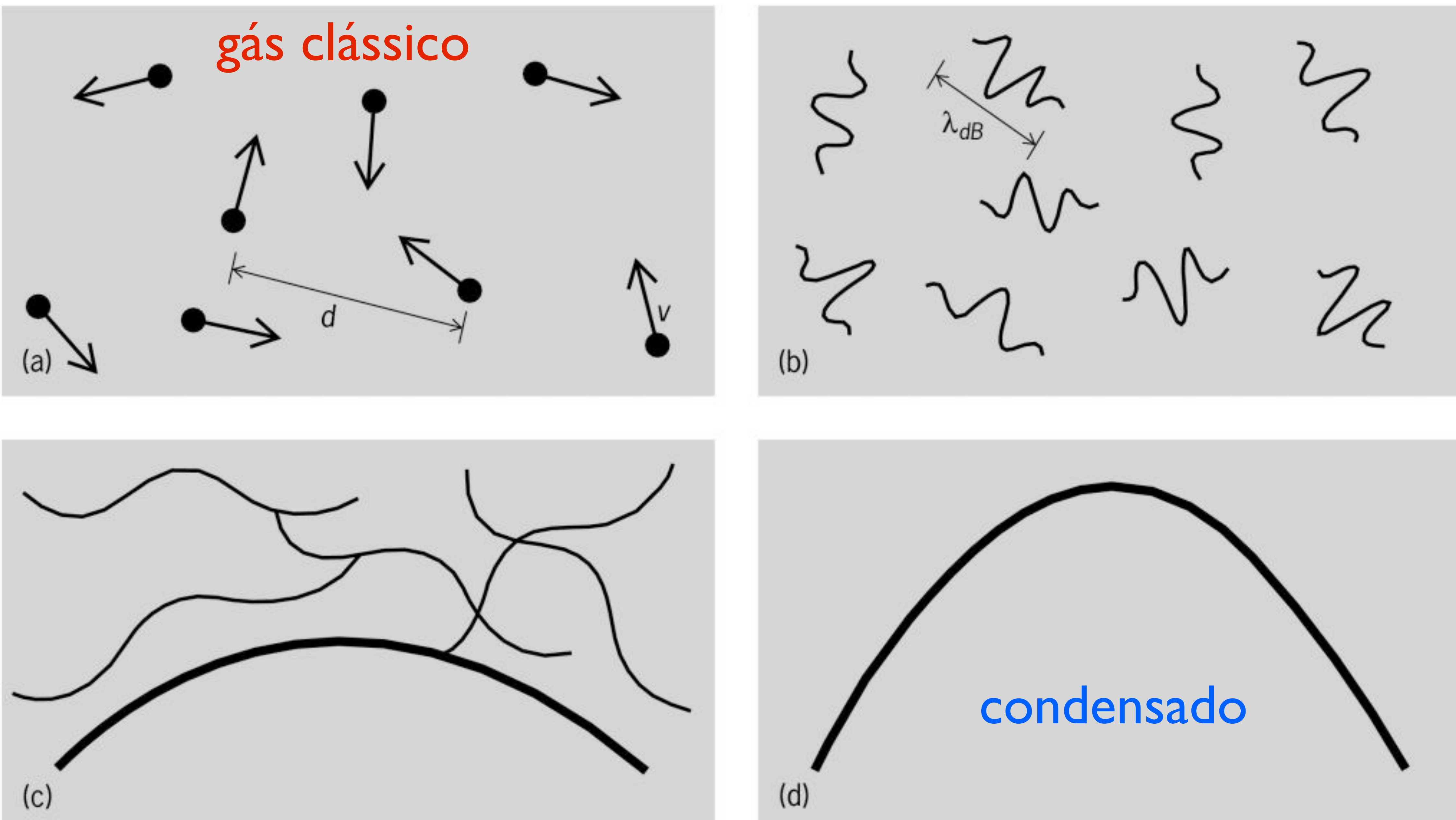
$$N_e = N$$

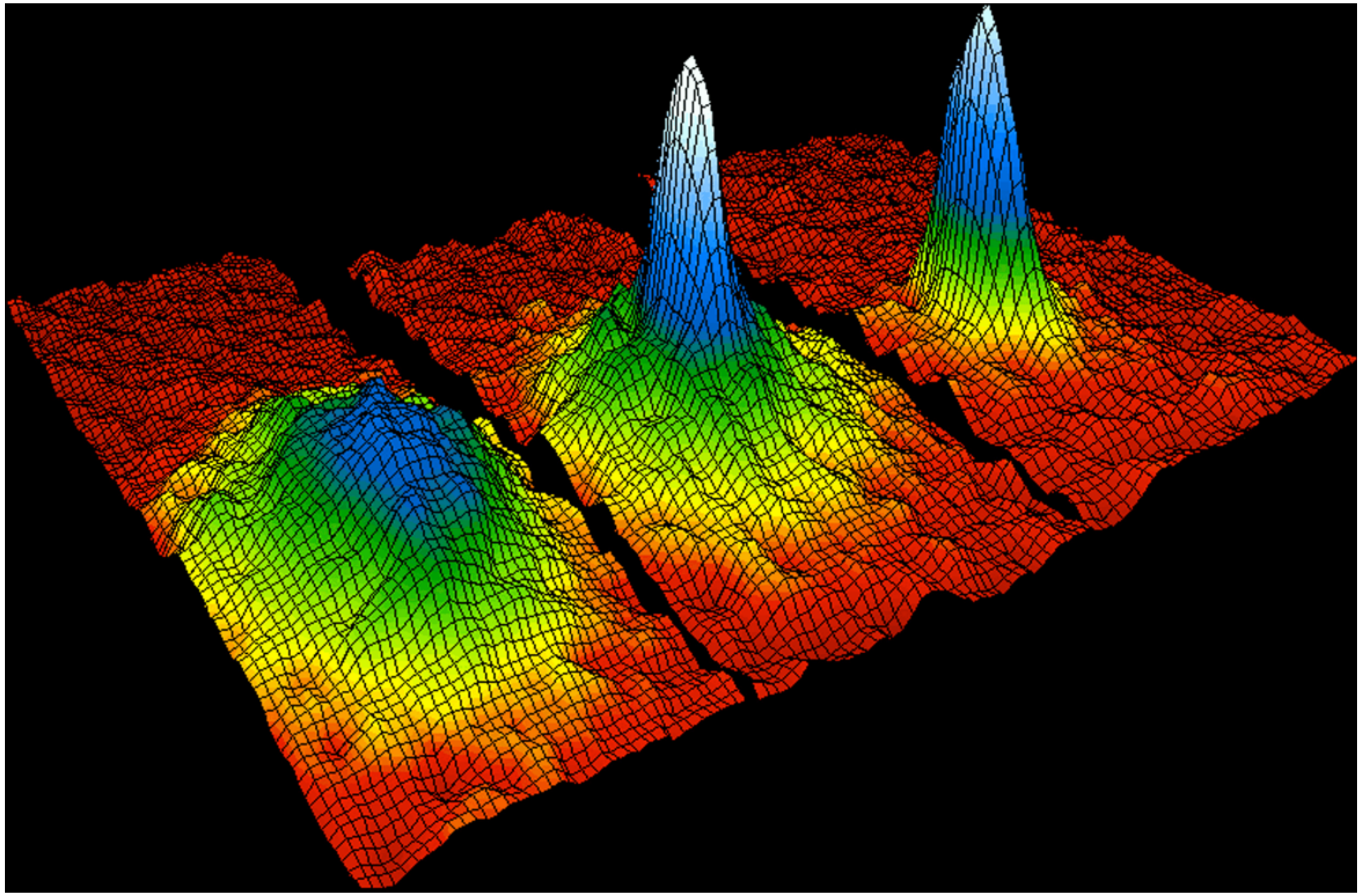
Limite termodinâmico:

$$\lim_{N,V\to\infty} \frac{N_0}{V} = 0$$

(gás normal)

Do regime clássico ao quântico

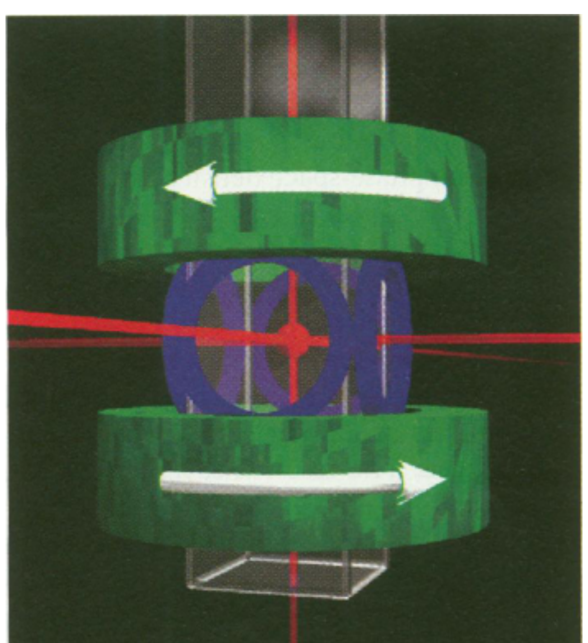




Desafio experimental: gás fracamente interagente em baixas temperaturas.

$$T_c \propto (N/V)^{2/3}$$

Science (1995)



Observation of Bose-Einstein Condensation in a Dilute Atomic Vapor

M. H. Anderson, J. R. Ensher, M. R. Matthews, C. E. Wieman,* E. A. Cornell

A Bose-Einstein condensate was produced in a vapor of rubidium-87 atoms that was confined by magnetic fields and evaporatively cooled. The condensate fraction first appeared near a temperature of 170 nanokelvin and a number density of 2.5×10^{12} per cubic centimeter and could be preserved for more than 15 seconds. Three primary signatures of Bose-Einstein condensation were seen. (i) On top of a broad thermal velocity distribution, a narrow peak appeared that was centered at zero velocity. (ii) The fraction of the atoms that were in this low-velocity peak increased abruptly as the sample temperature was lowered. (iii) The peak exhibited a nonthermal, anisotropic velocity distribution expected of the minimum-energy quantum state of the magnetic trap in contrast to the isotropic, thermal velocity distribution observed in the broad uncondensed fraction.