

# **Disorder induced shift of condensation temperature for dilute trapped Bose gases**

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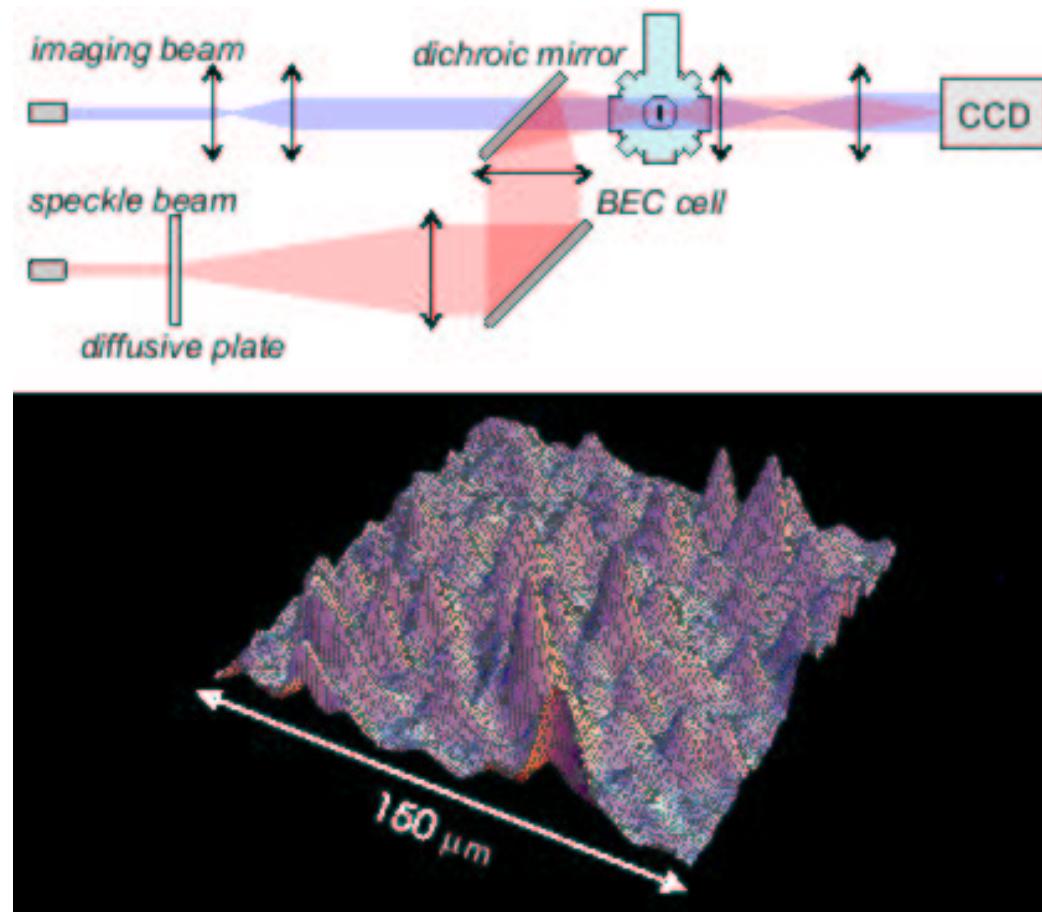


- 1. Introduction: disordered bosons**
- 2. Shift of the critical temperature**
- 3. Summary and outlook**

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# I. Introduction: disordered bosons

Experimental realization of disorder: magneto-optical trap



Inguscio *et al.*, PRL 95, 070401 (2005)

## Model system

**simplification:** no interaction (not necessary in first order perturbation theory)

**start:** action of the Bose gas

$$\mathcal{A}[\psi^*, \psi] = \int_0^{\hbar\beta} d\tau \int d^3x \psi^*(\mathbf{x}, \tau) \left[ \hbar \frac{\partial}{\partial \tau} - \frac{\hbar^2}{2M} \Delta + V(\mathbf{x}) + U(\mathbf{x}) - \mu \right] \psi(\mathbf{x}, \tau)$$

**properties:**

- disorder potential  $V(\mathbf{x})$
- trap  $U(\mathbf{x})$
- chemical potential  $\mu$
- periodic Bose fields  $\psi(\mathbf{x}, \tau + \hbar\beta) = \psi(\mathbf{x}, \tau)$

## Disorder potential

**assumptions:**

Gaussian distributed random potential

$$\overline{V(\mathbf{x}_1)} = 0 , \quad \overline{V(\mathbf{x}_1)V(\mathbf{x}_2)} = R(\mathbf{x}_1 - \mathbf{x}_2)$$

**disorder average:**

$$\overline{\bullet} = \int \mathcal{D}V \bullet \exp \left\{ -\frac{1}{2} \int d^3x \int d^3x' R^{-1}(\mathbf{x} - \mathbf{x}') V(\mathbf{x}) V(\mathbf{x}') \right\}$$

**examples:**

- Gaussian correlation:  $R(\mathbf{x}) = \frac{R}{(2\pi\xi^2)^{3/2}} e^{-\frac{\mathbf{x}^2}{2\xi^2}}$
- Lorentzian correlation:  $R(\mathbf{x}) = \frac{R}{4\pi\xi^2} \frac{1}{|\mathbf{x}|} e^{-\frac{|\mathbf{x}|}{\xi}}$

## II. Shift of the critical temperature

interaction	disorder
repulsive interaction	<b>effective attractive interaction</b> Graham and Pelster, cond-mat/0508306
$\frac{\Delta T_c}{T_c^{(0)}} = -3.426 \frac{a}{\lambda_c^{(0)}}$ Giorgini et al., PRA <b>54</b> , R4633 (1996) Gerbier et al., PRL <b>92</b> , 030405 (2004)	$\frac{\Delta T_c}{T_c^{(0)}} = c(\xi)R$ $c(\xi) > 0$
$U_{\text{int}}(\mathbf{x}, \mathbf{x}') = \frac{4\pi\hbar^2 a}{M} \delta(\mathbf{x} - \mathbf{x}')$	$R(\mathbf{x} - \mathbf{x}')$

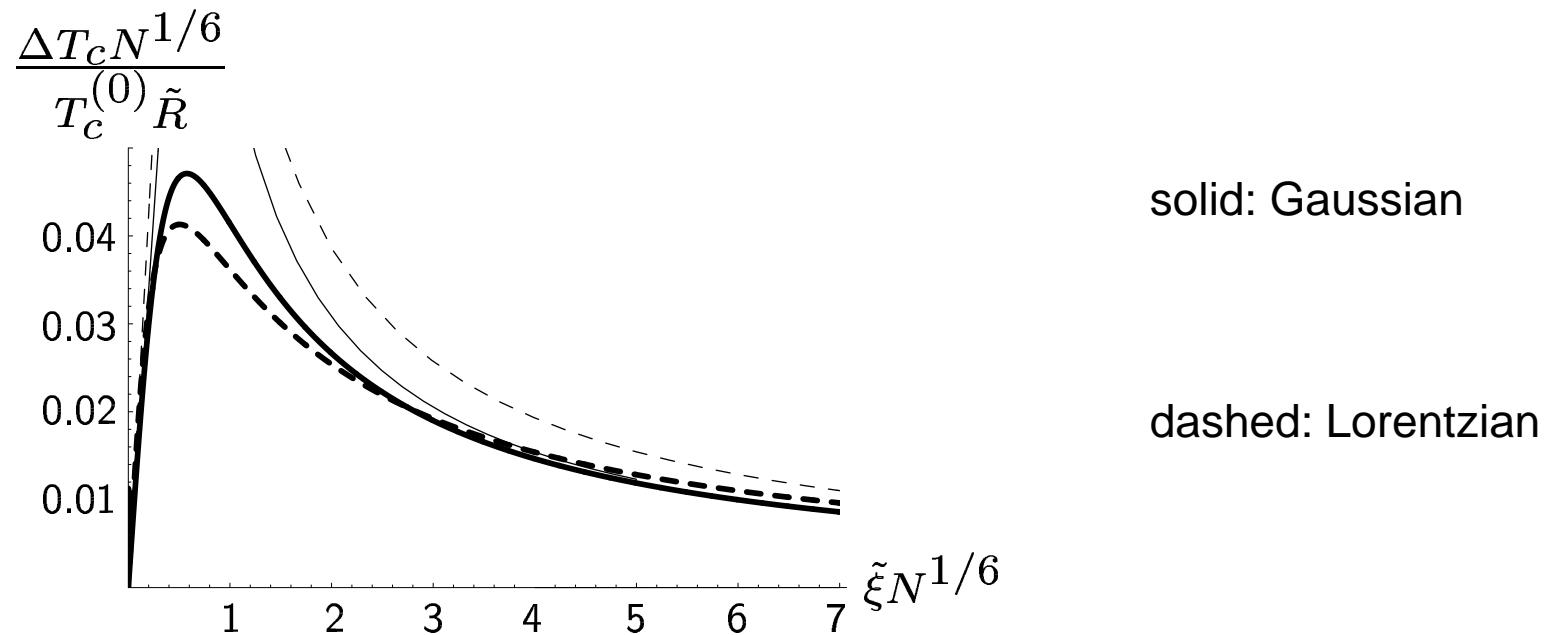
$$T_c^{(0)} = \frac{\hbar\omega_g}{k_B} \left[ \frac{N}{\zeta(3)} \right]^{1/3}$$

$$\omega_g = (\omega_1\omega_2\omega_3)^{1/3}$$

**procedure:**  $n = n(\mu), \quad \mu \nearrow \mu_c \quad \Rightarrow \quad T_c$

**method:** first order perturbation theory in  $R$

## Results



**length scale:**

$$l_{\text{os}} = \sqrt{\frac{\hbar}{M\omega_g}} , \quad \omega_g = (\omega_1\omega_2\omega_3)^{1/3}$$

**dimensionless units:**

$$\tilde{\xi} = \frac{\xi}{l_{\text{os}}} , \quad \tilde{R} = \frac{R}{\left(\frac{\hbar^2}{Ml_{\text{os}}^2}\right)^2 l_{\text{os}}^3}$$

Timmer, Pelster, and Graham, EPL **76**, 760 (2006)

## Florence experiment (group of M. Inguscio)

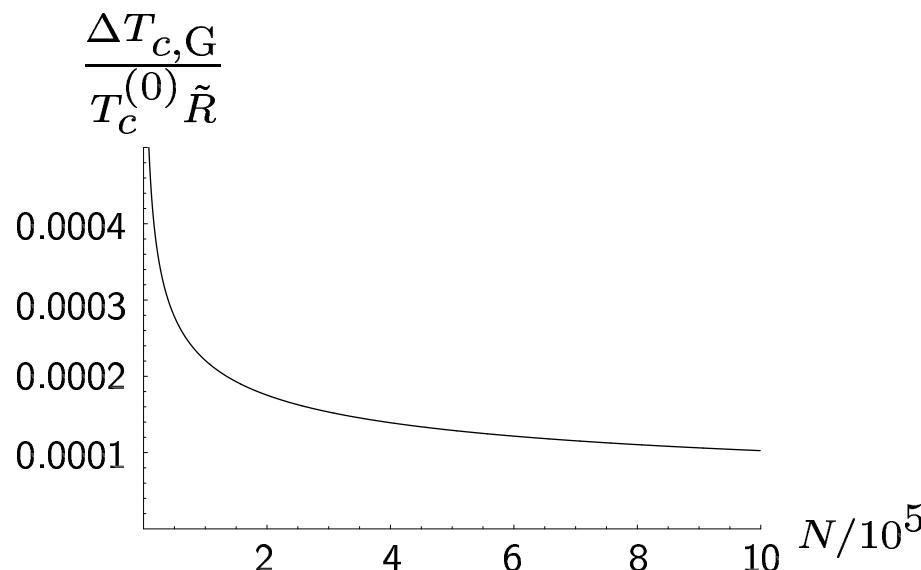
trap:

$^{85}\text{Rb}$

$N = 3 \cdot 10^5$

$\omega_g = 2\pi \cdot 40 \text{ Hz}$

$l_{\text{os}} = 1.72 \mu\text{m}$



laser speckles:

correlation length:  $\xi = 10 \mu\text{m}$  ,  $\tilde{\xi} = 5.88$

disorder strength:  $\tilde{R} = 200$

estimate with Gaussian correlation:  $\frac{\Delta T_c}{T_c^{(0)}} = 0.03$

### III. Summary and outlook

- calculated shift of critical temperature of dilute trapped Bose gas using first order perturbation theory
- result: disorder-averaged  $\Delta T_c$  for any spatially isotropic correlation and arbitrary correlation length
- shift has maximum with respect to correlation length
- reason: transition between important length scales: mean particle distance  $\leftrightarrow$  size of trap
- should be possible to measure shift
- further project: standard deviation of  $\Delta T_c$  in sample to sample fluctuations