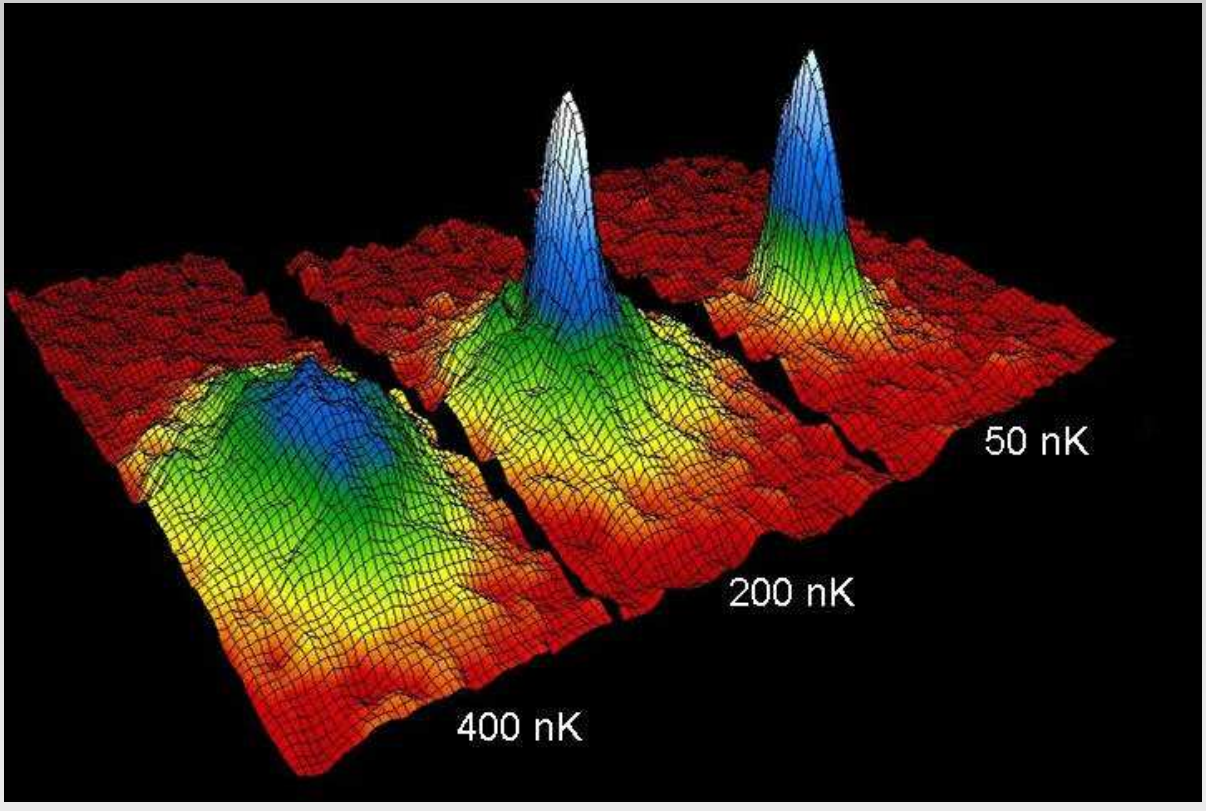
Ultracold Quantum Gases



Aristeu Lima

Free University of Berlin

Outline of the talk

- Brief historic remarks

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- Bose-Einstein condensation (BEC)

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- Spinor Fermi gases

Historical remarks

- 1924: S. N. Bose and the bosons

Historical remarks

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- 1924: A. Einstein

Überreicht vom Verfasser.

SITZUNGSBERICHTE 1925. I.

DER PREUSSISCHEN

AKADEMIE DER WISSENSCHAFTEN.

Sitzung der physikalisch-mathematischen Klasse vom 8. Januar.

Quantentheorie des einatomigen idealen Gases.

Zweite Abhandlung.

Von A. Einstein.

Historical remarks

- 1924: S. N. Bose and the bosons
- 1924: A. Einstein
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- 1924: A. Einstein
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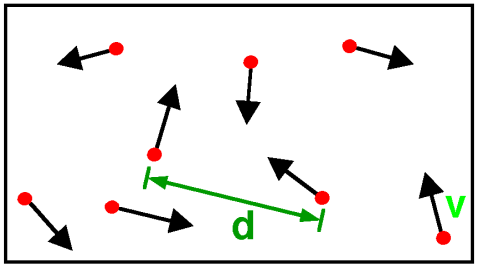
- 1957: J. Bardeen, L. N. Cooper, and J. R. Schrieffer

Microscopic Theory of Superconductivity

Historical remarks

- 1924: S. N. Bose and the bosons
- 1924: A. Einstein
- 1926: E. Fermi and the fermions
- 1957: J. Bardeen, L. N. Cooper, and J. R. Schrieffer
- 1995: E. A. Cornell, C. E. Wieman, and W. Ketterle

Bose-Einstein Condensation



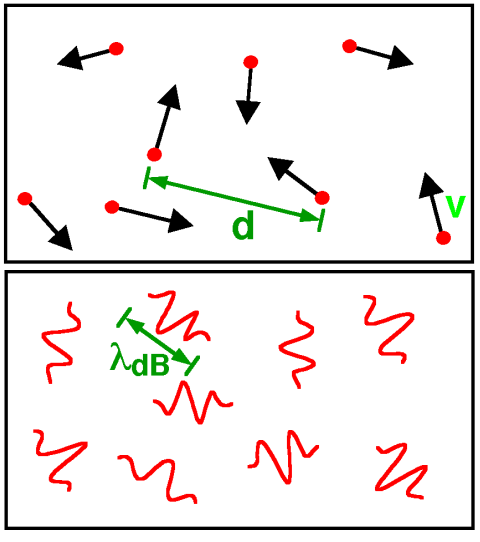
High Temperature T:

thermal velocity v

density d^{-3}

"Billiard balls"

Bose-Einstein Condensation



High Temperature T:

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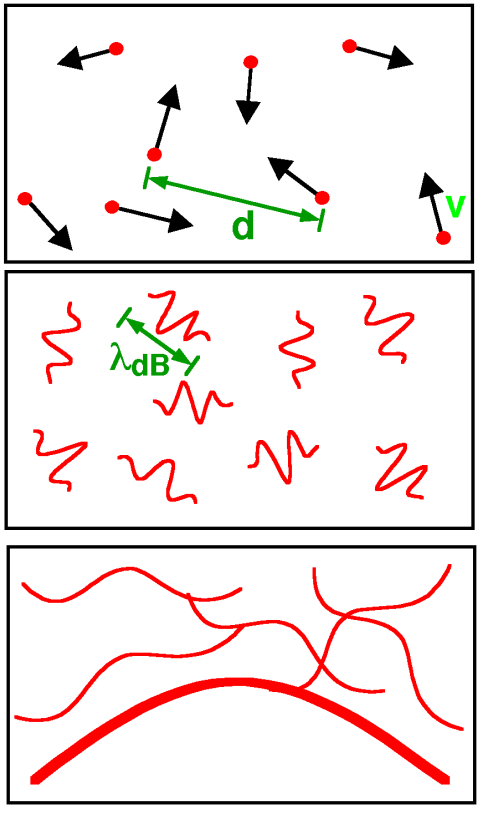
Low Temperature T:

De Broglie wavelength

$\lambda_{dB}=h/mv \propto T^{-1/2}$

"Wave packets"

Bose-Einstein Condensation



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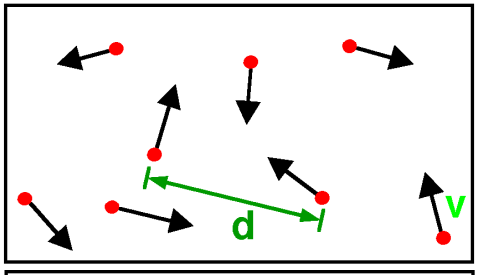
$\lambda_{dB} \approx d$

"Matter wave overlap"

Bose-Einstein Condensation



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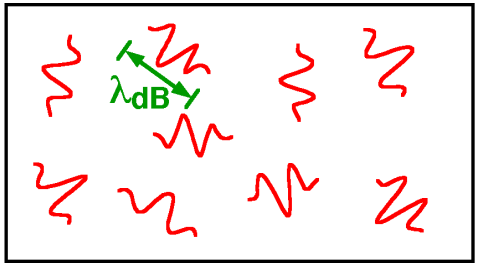

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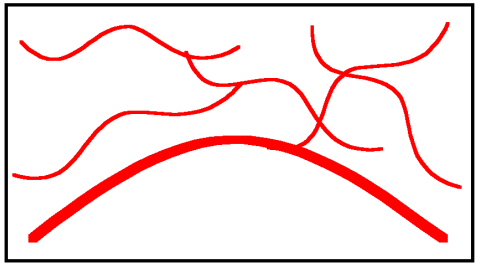

$T=T_{crit}$: Bose-Einstein Condensation

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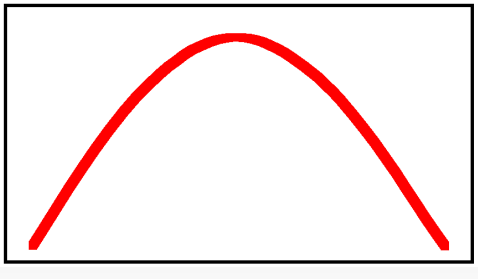
"Matter wave overlap"



T=0: Pure Bose condensate

"Giant matter wave"

Bose-Einstein Condensation

- Laser cooling and Trapping (Nobel 1997)

Bose-Einstein Condensation

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Bose-Einstein Condensation

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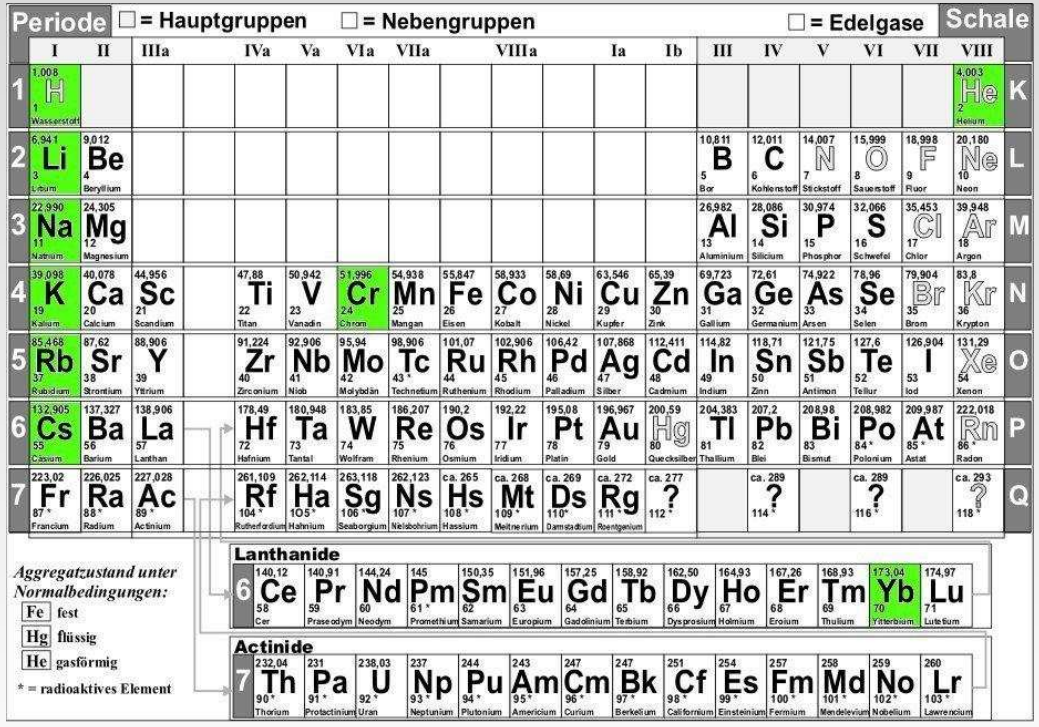
- Condensed elements

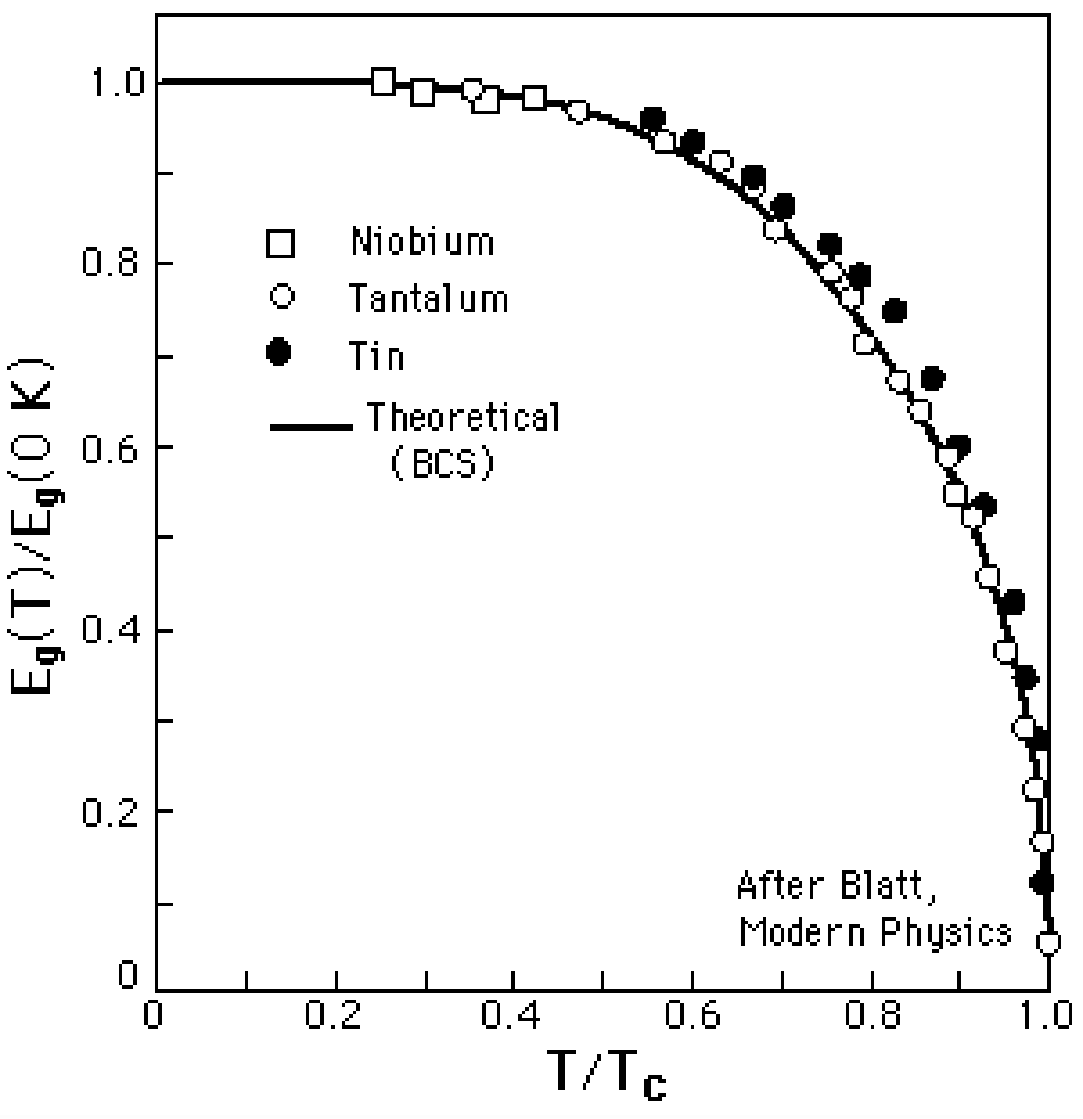


BCS superconductivity

- Bardeen, Cooper and Schrieffer: Nobel Prize 1972

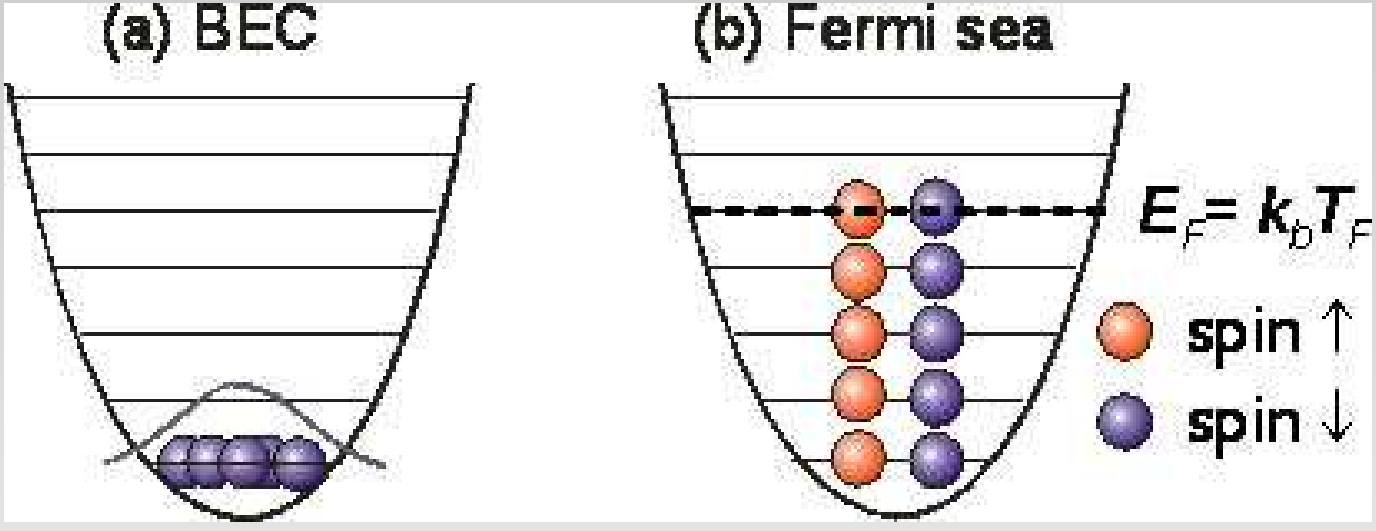
BCS superconductivity

- Universality of the energy gap



BCS-BEC crossover

Bose agglomerate versus Fermi sea



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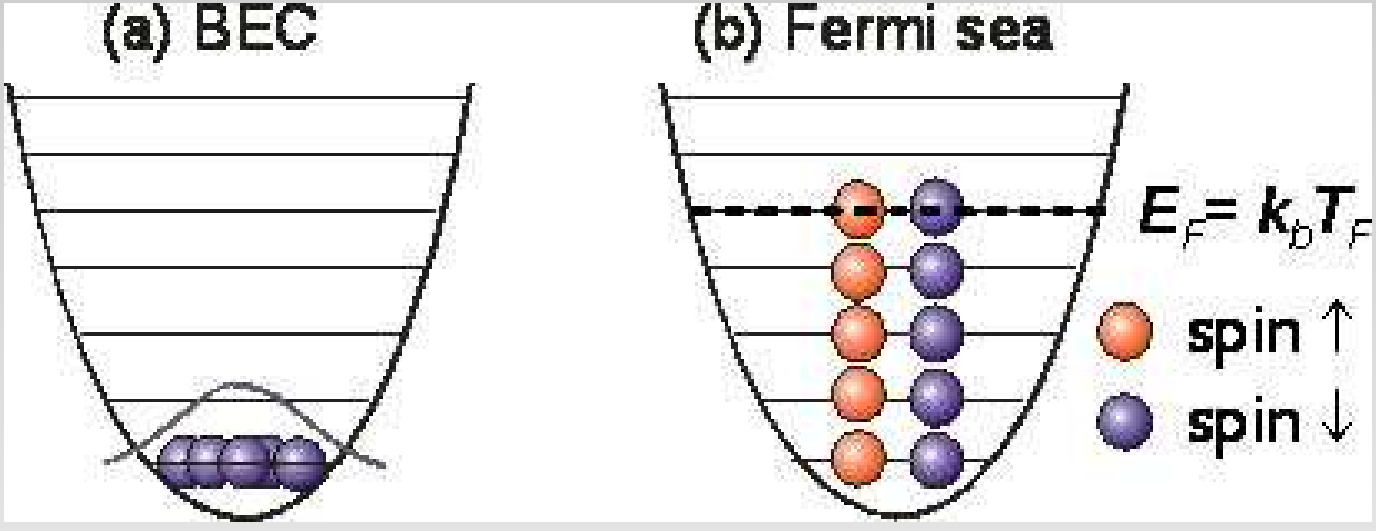
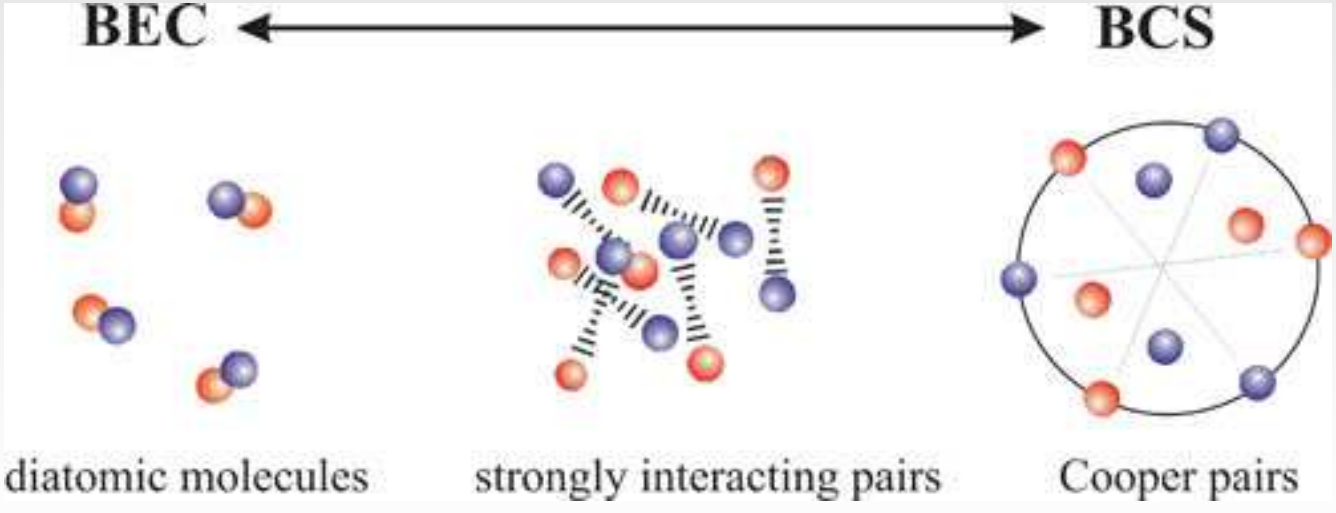
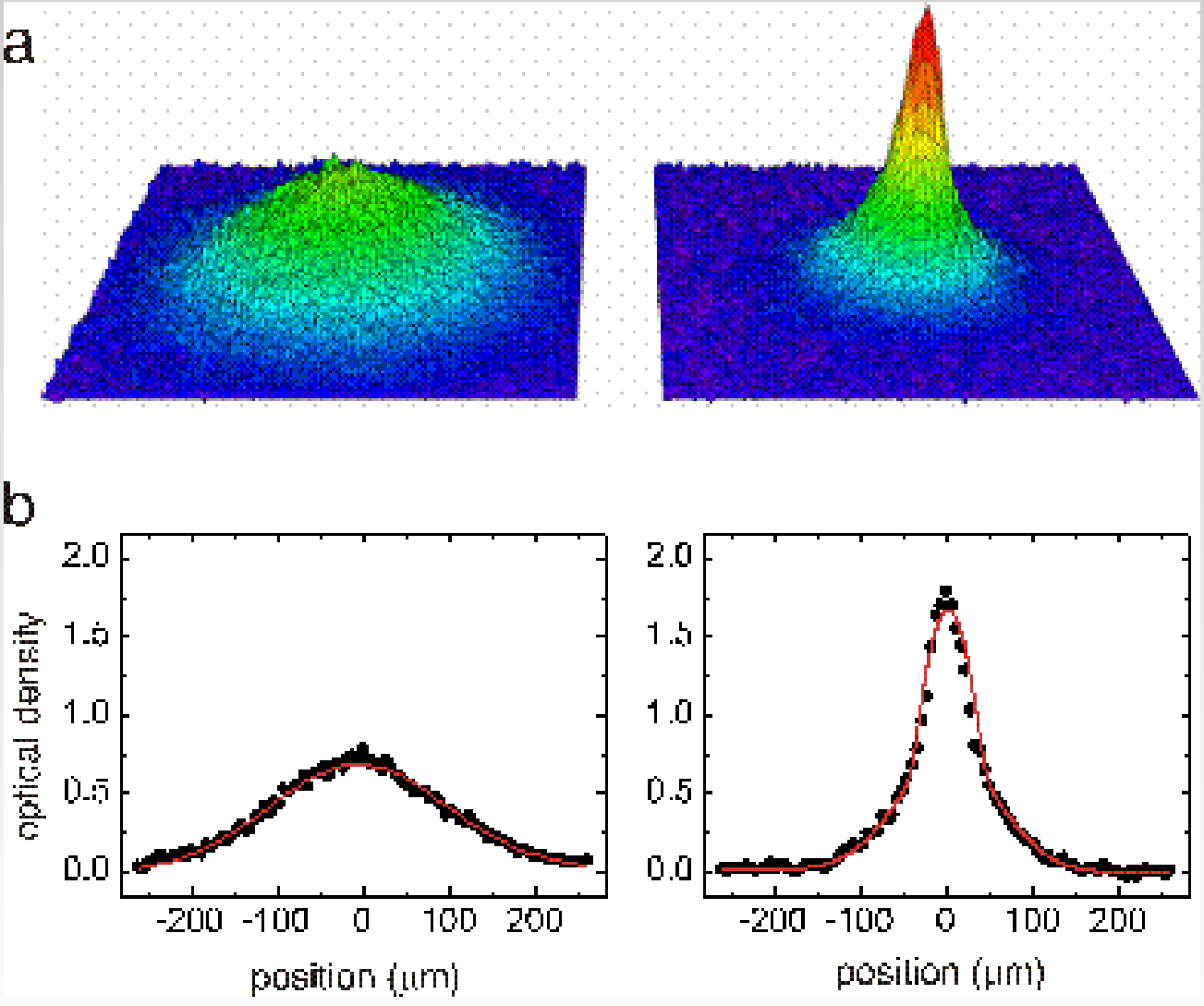




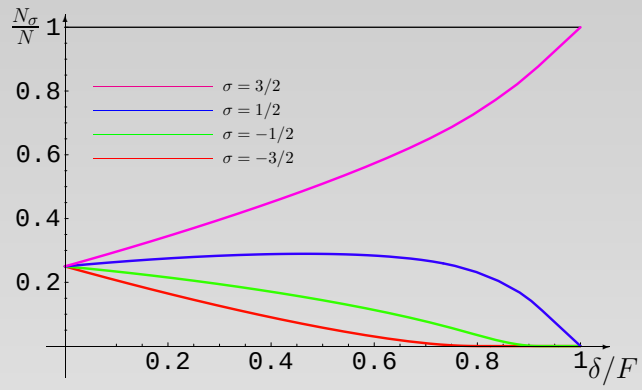
BCS-BEC crossover

Molecules and Cooper Pairs

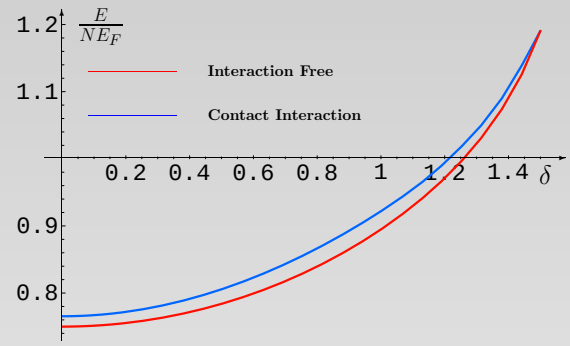


Spinor Fermi gases

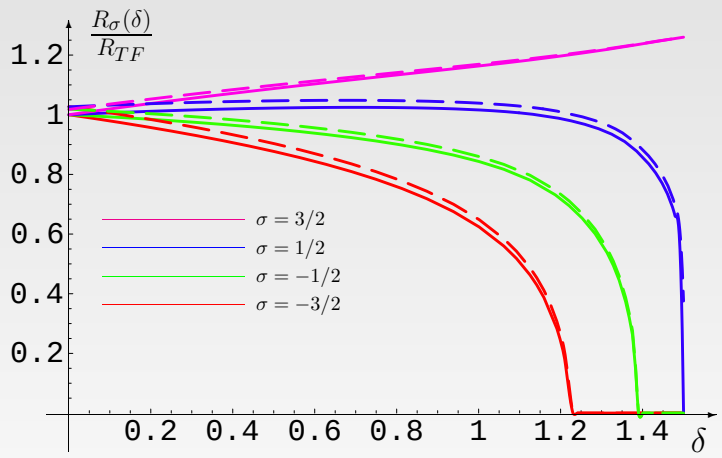
Zeeman Populations



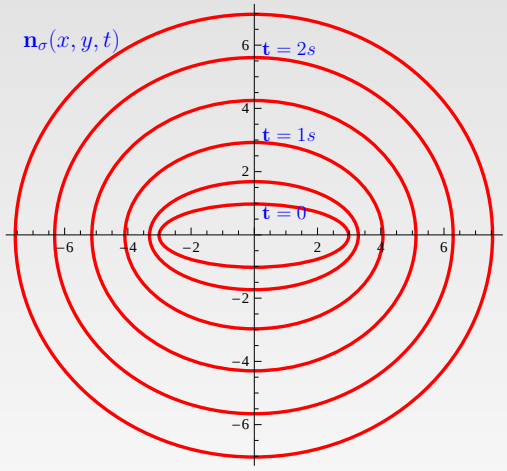
Internal Energy



Thomas-Fermi Radii

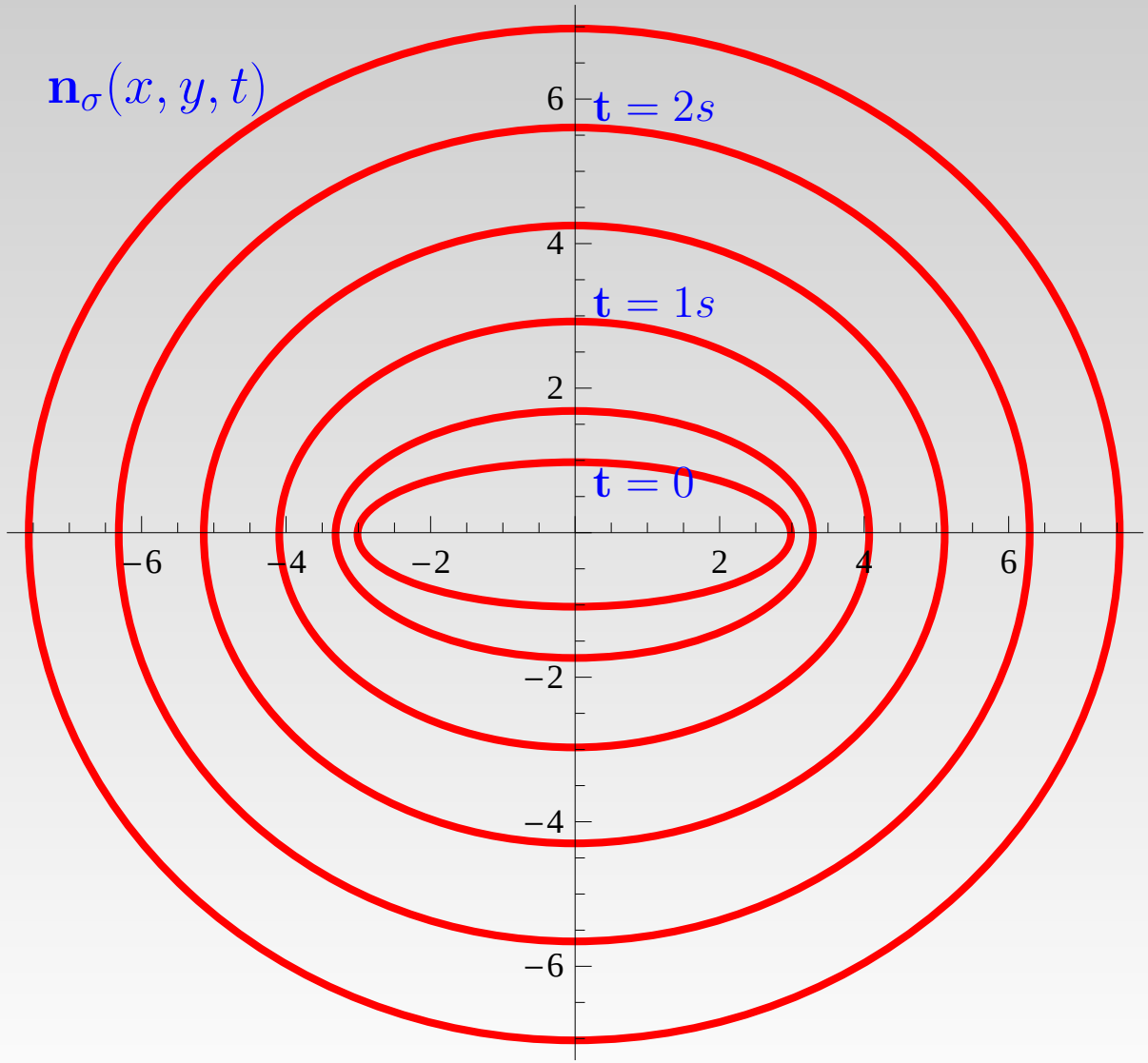


Expansion

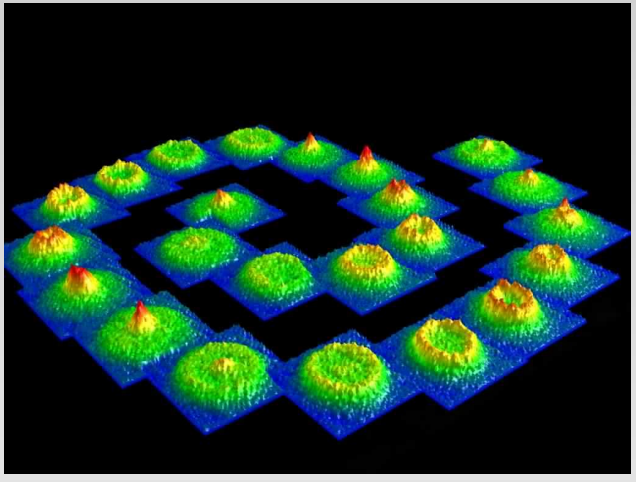


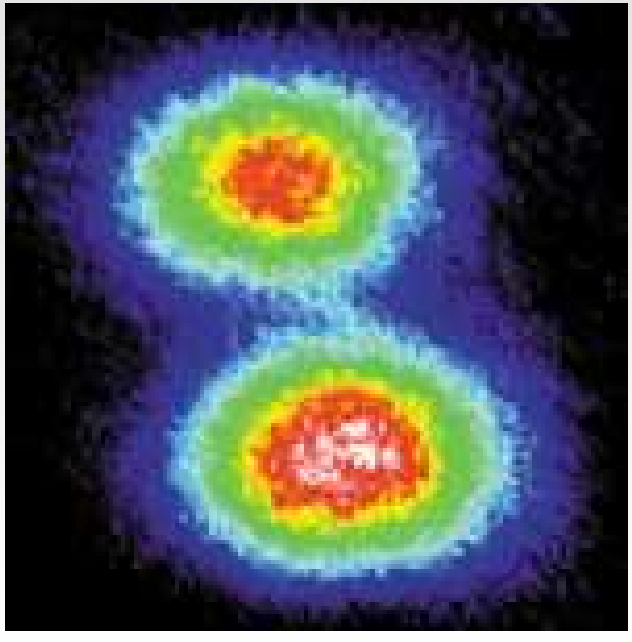
Proceedings of Path Integrals: Trends and Perspectives

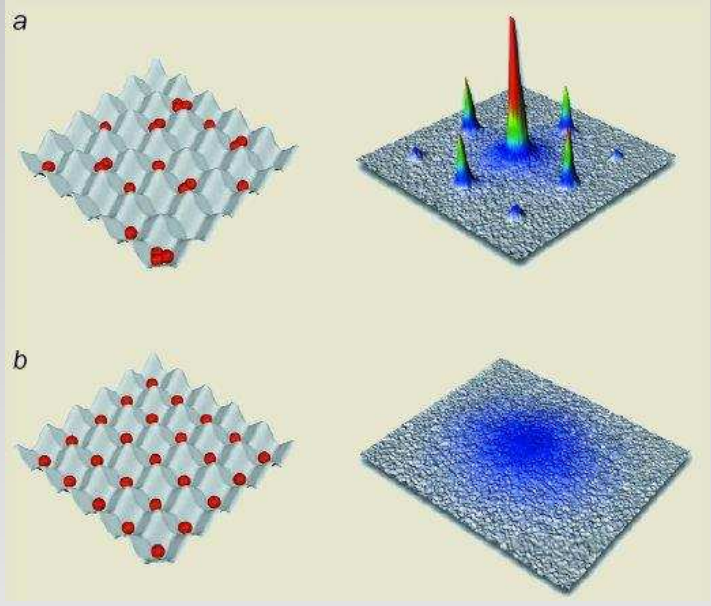
Spinor Fermi gases: Expansion

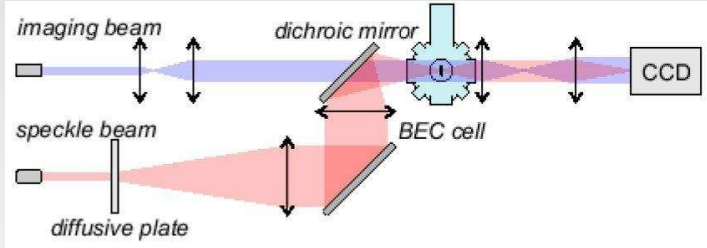


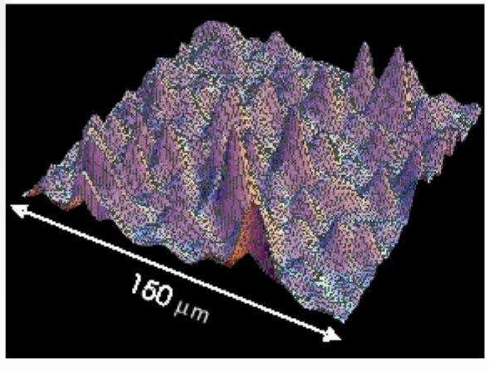
Outlook











Unordnung

Thanks

- DAAD German Academic Exchange Service

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- DFG-Priority Program SPP 1116: *Interactions in Ultra-Cold Atomic and Molecular Gases*

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- Cold atoms group FU-Berlin

Laser Cooling

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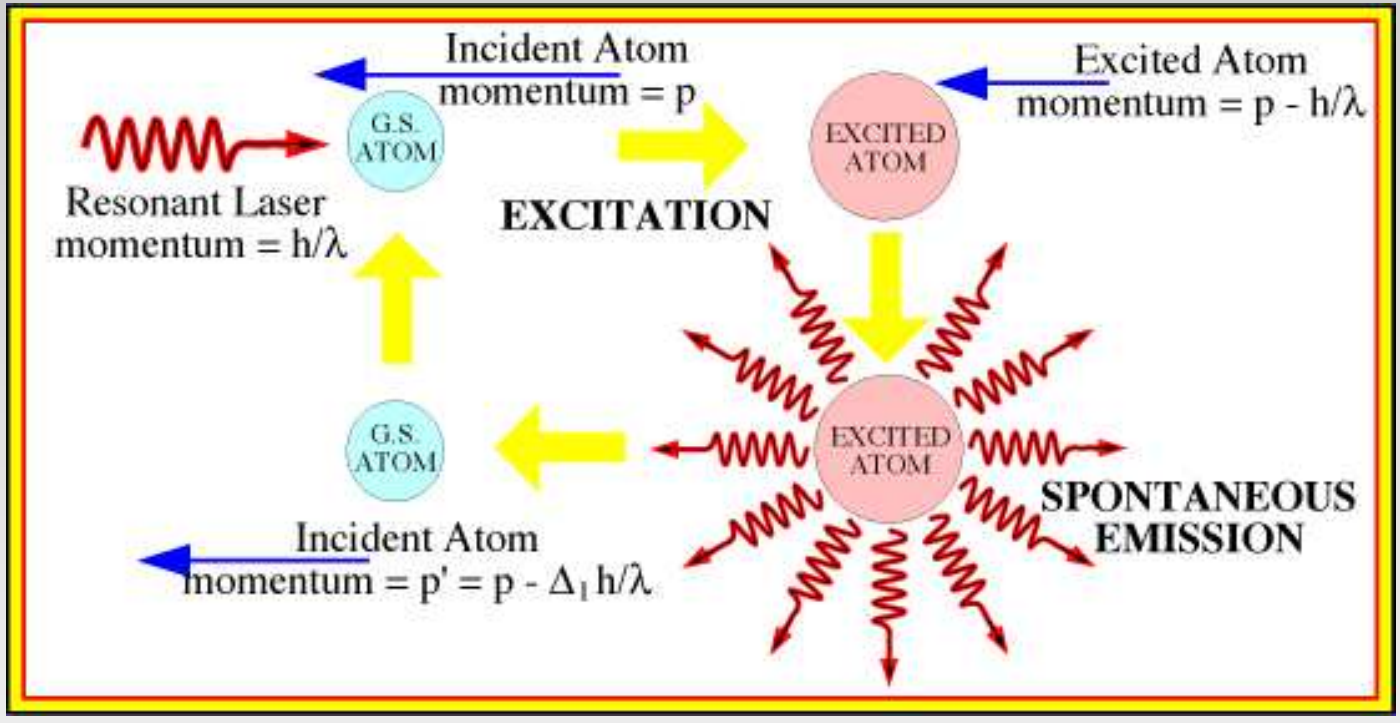

Evaporative cooling

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