Quantum Fluids

1: Bose-Einstein Condensation

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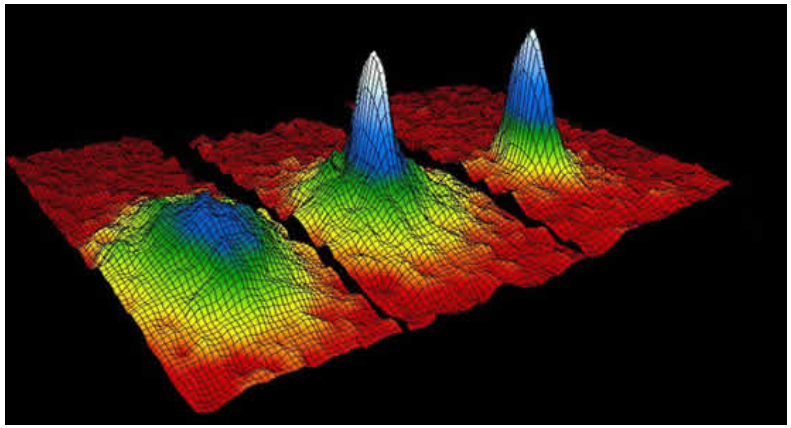
- System size: a few μm
- Lifetime: seconds
- Detection: Photo of actual density!



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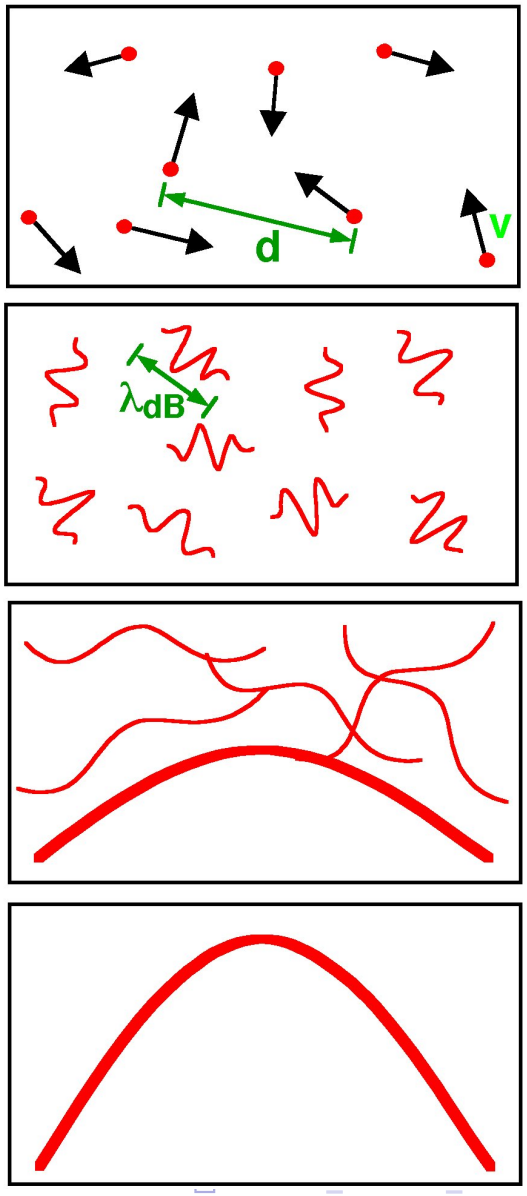

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- $3N$-dimensional space: the problem scales exponentially with number of particles. (L^{3N})
- Historically: Solid materials, nuclei, or liquid helium. Now have quantum *gases* - more versatile

Textbook derivation of BEC
(blackboard lecture)

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- 1986: High-Tc superconductivity: Bednorz and Mller
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- 2003: BCS transition for cold Fermi atoms (Jin)
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- Phenomena close to $T = 0$
- Ground state – mean-field approximation
- Lowest excited many-body states: Bogoliubov theory
- Minimize free energy or use Boltzmann's law to deduce finite-T properties

Gross-Pitaevskii equation
(blackboard lecture)

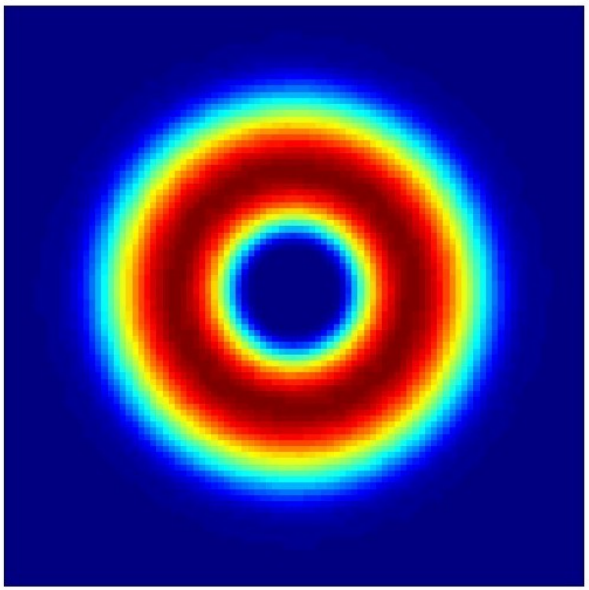
Gross-Pitaevskii equation

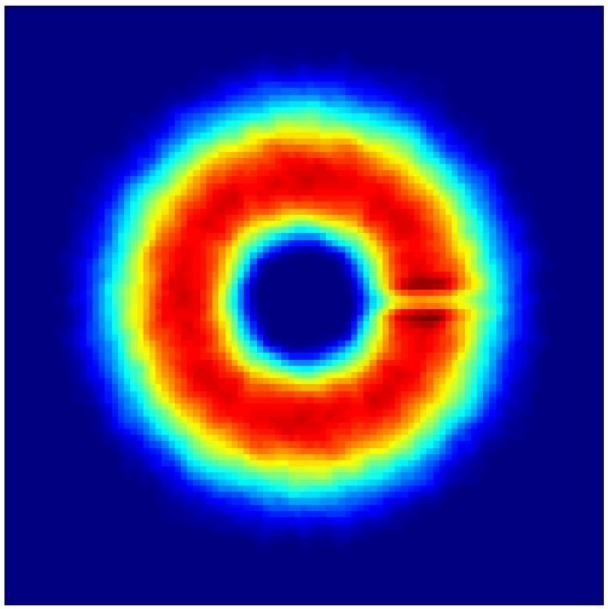
$$i\hbar\frac{\partial\Psi}{\partial t} = -\frac{\hbar^2}{2m}\nabla^2\Psi + V(r)\Psi + U_0|\Psi|^2\Psi$$

GPE is used to simulate: ...

Gross-Pitaevskii equation

Ground state in various traps ...

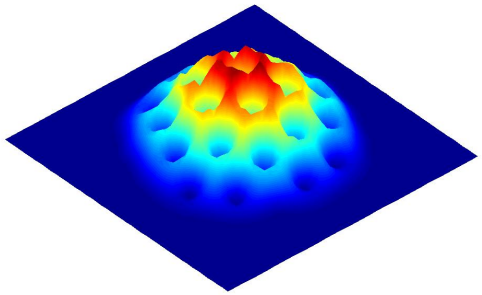




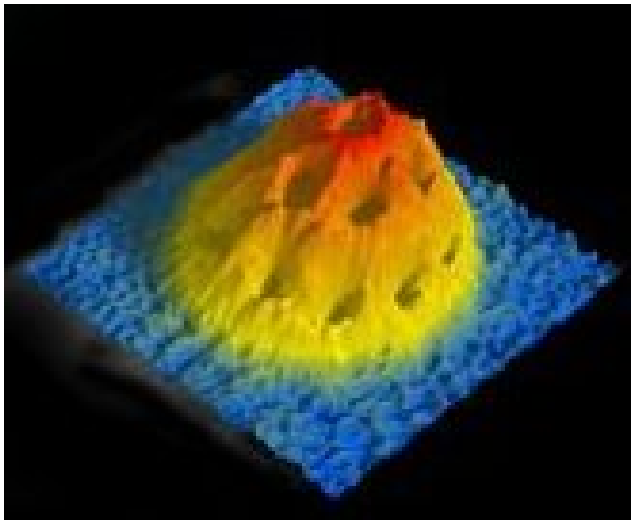
(BEC in a toroidal trap; work in progress)

Gross-Pitaevskii equation

... vortex lattices in rotated BECs ...



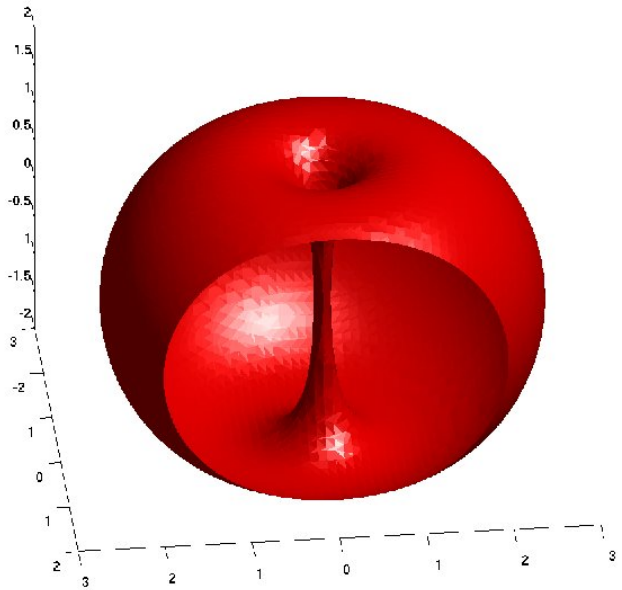
Theory

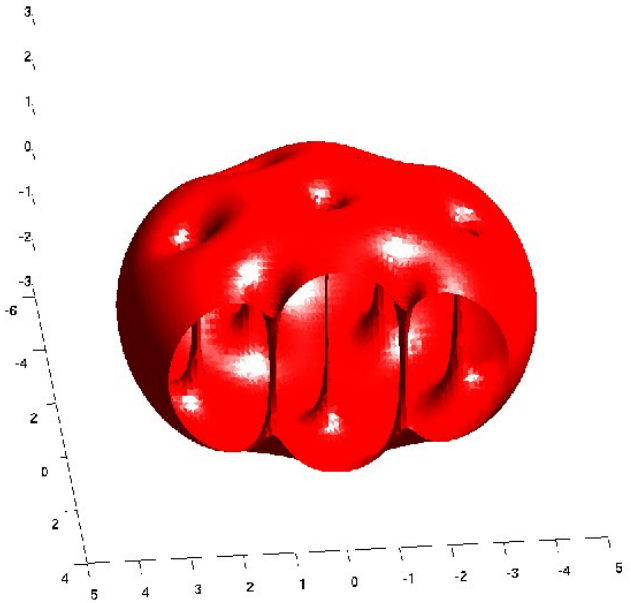


Experiment

Gross-Pitaevskii equation

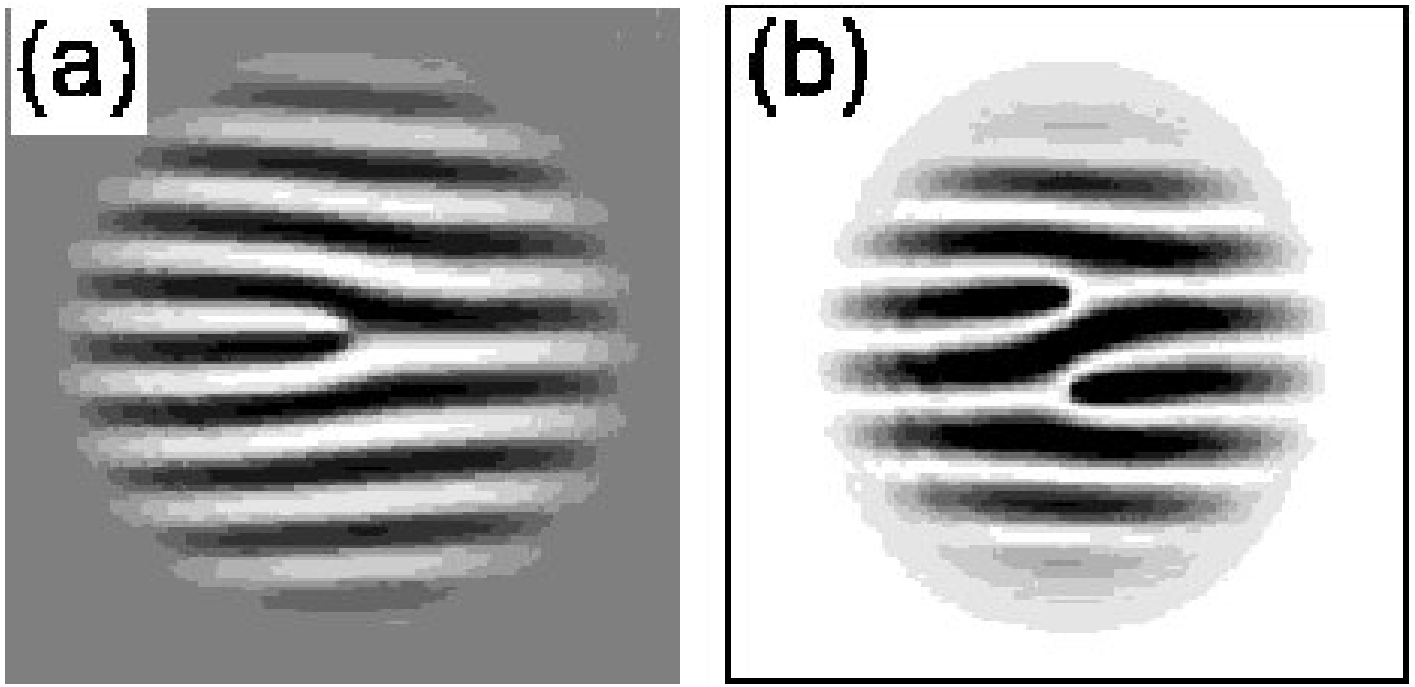
... More vortices (now in 3D) ...





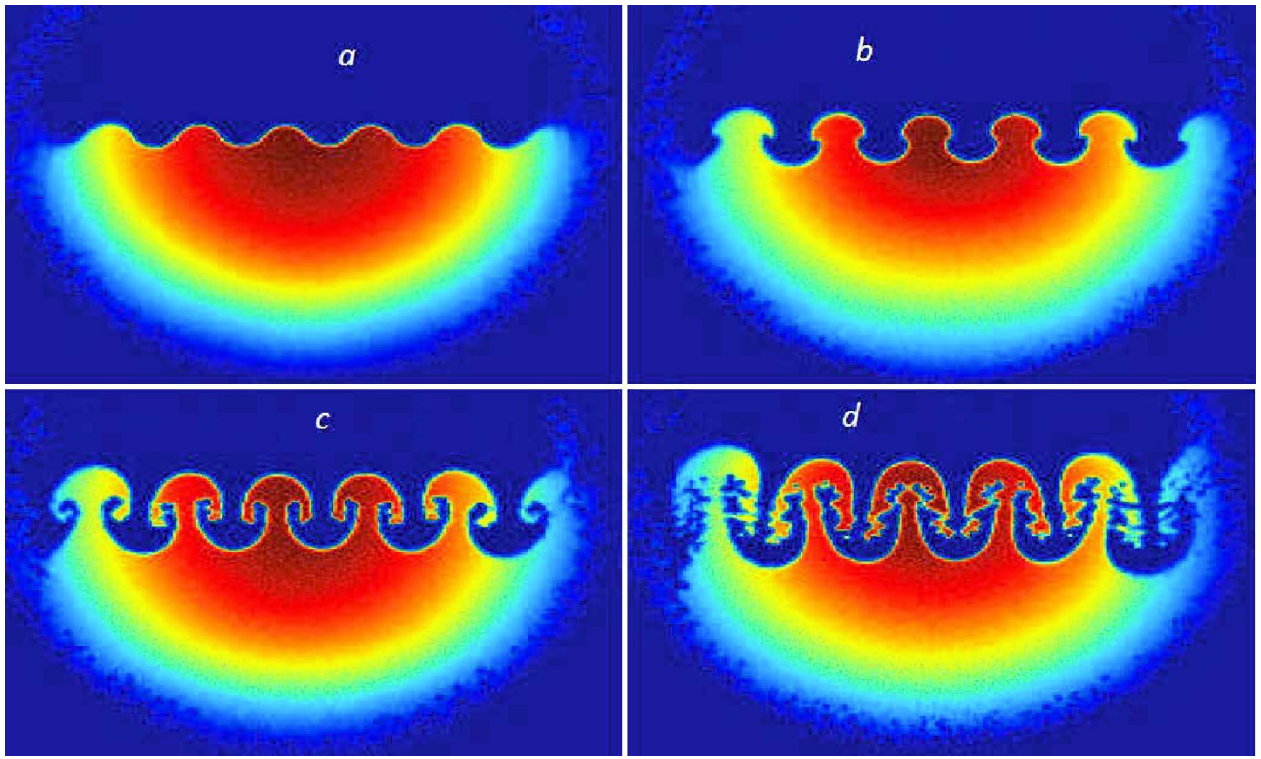
Gross-Pitaevskii equation

... coherence, correlations, interference fringes ...



Gross-Pitaevskii equation

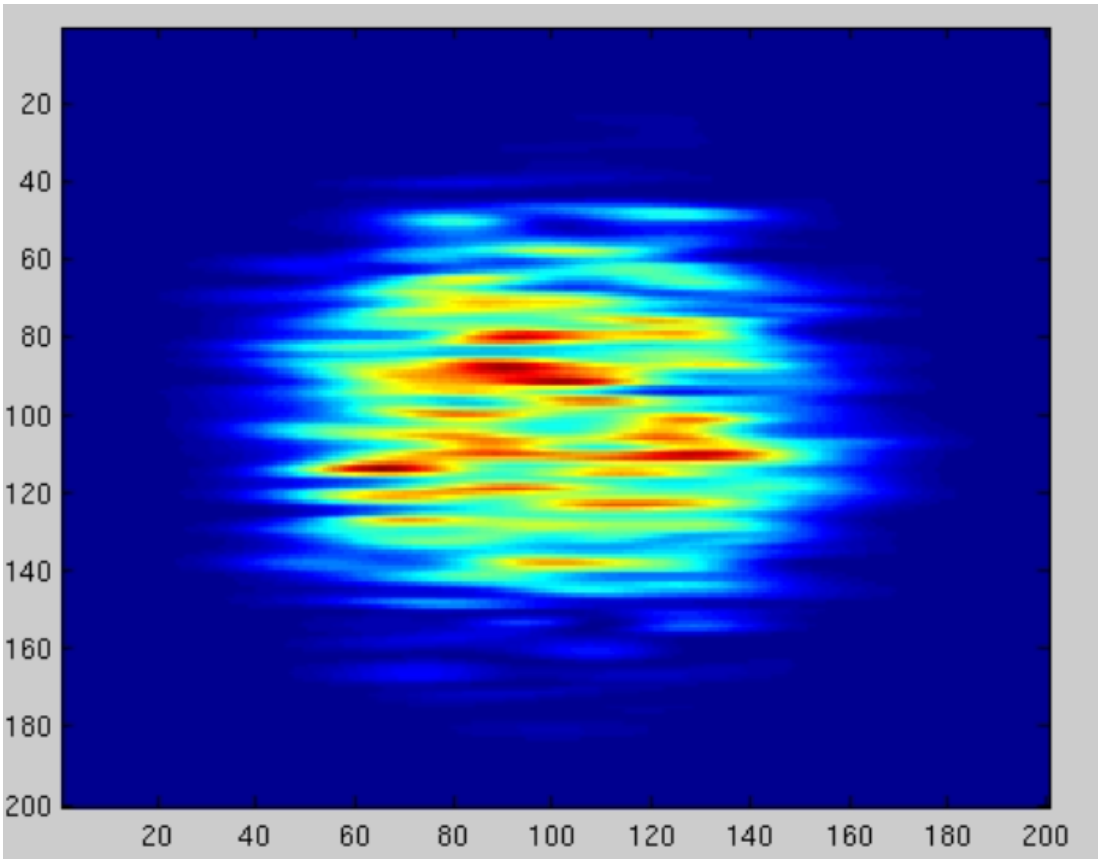
... systems of several condensates ...



Rayleigh-Taylor instability in an interface between two condensates

Gross-Pitaevskii equation

...even finite-temperature physics and critical phenomena (with modifications)



End of lecture

Thank you for your attention