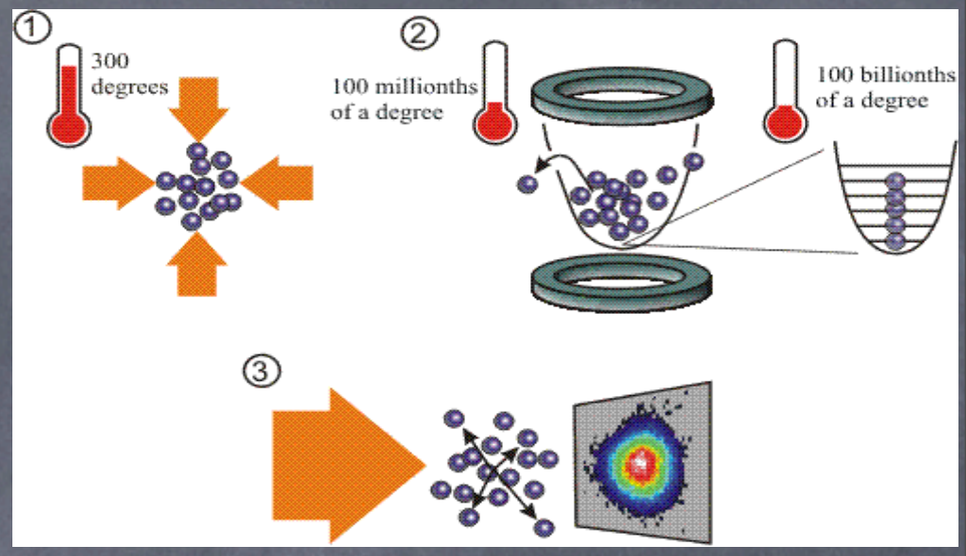
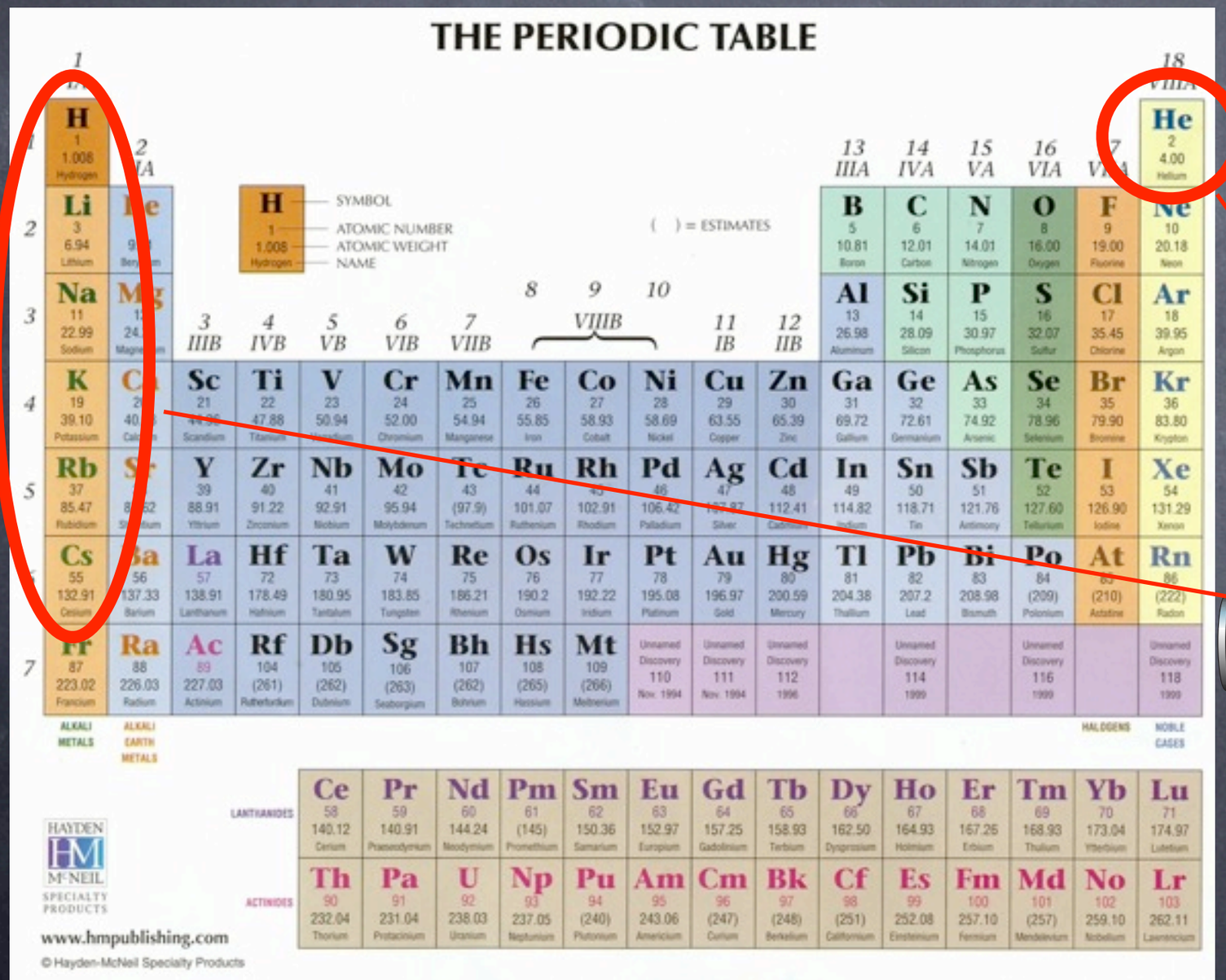
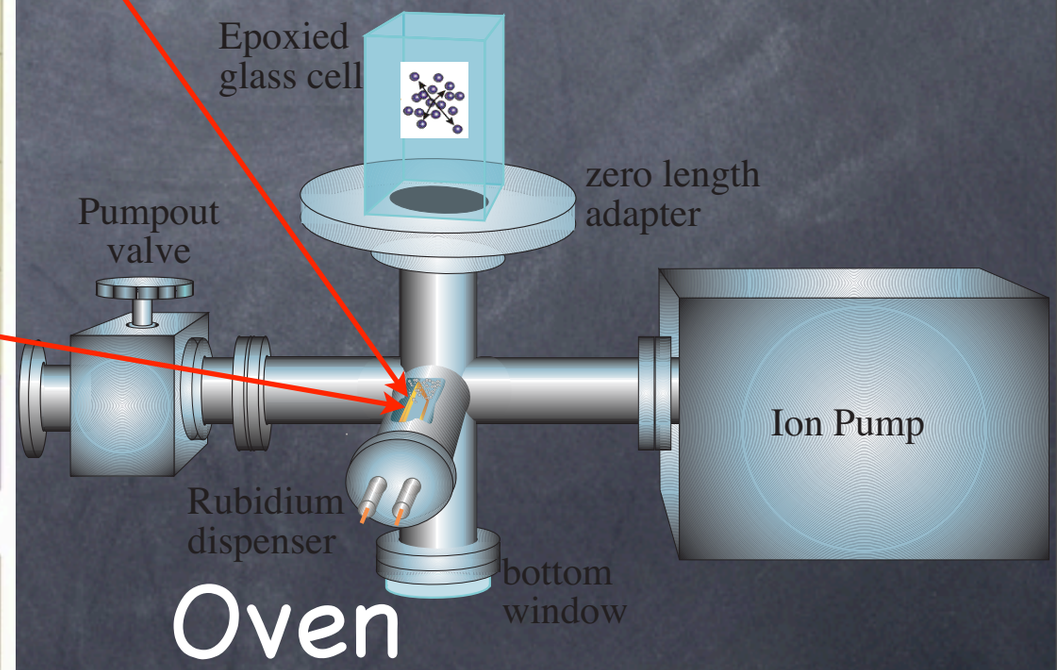
Atomic Gas Experiments





Trap

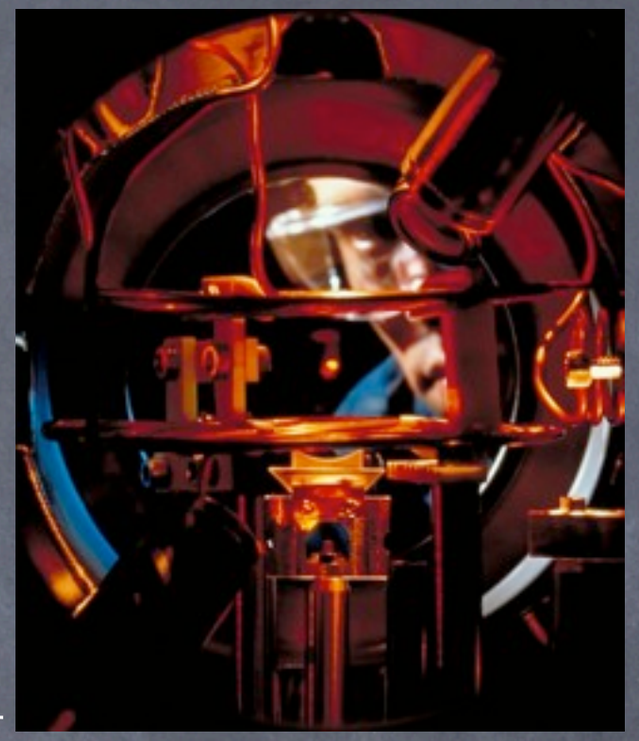


Oven

- Alkali atoms: H, Li, Na, K, ...
- N≈10-10^9
- Very dilute n≈10^{13}-10^{15}cm^{-3} (air n≈10^{19})
- Coldest place in the universe* T~0.45nK

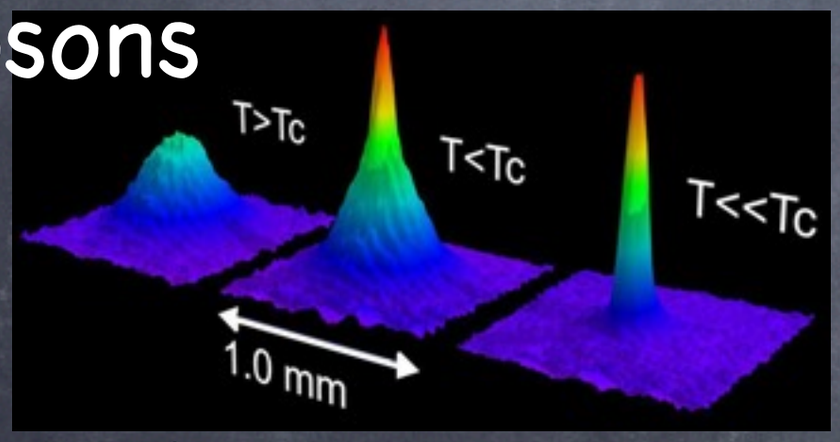
Guinness World Records 2008

$$n\lambda_T^3 \sim 1$$

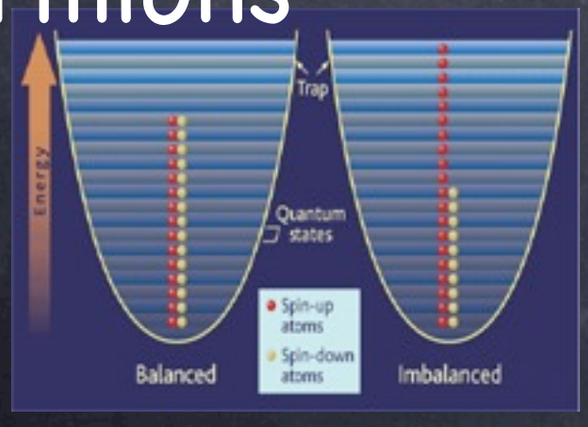


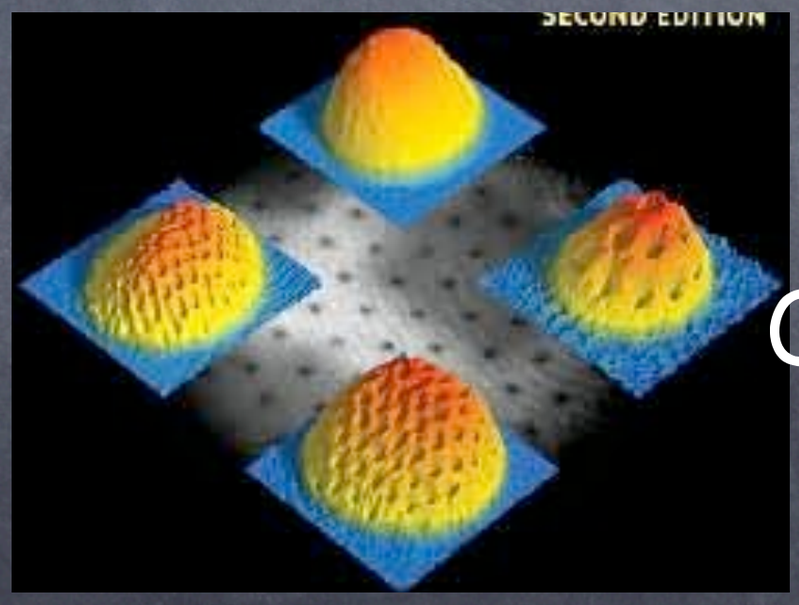
New Quantum Systems

Bosons



Fermions





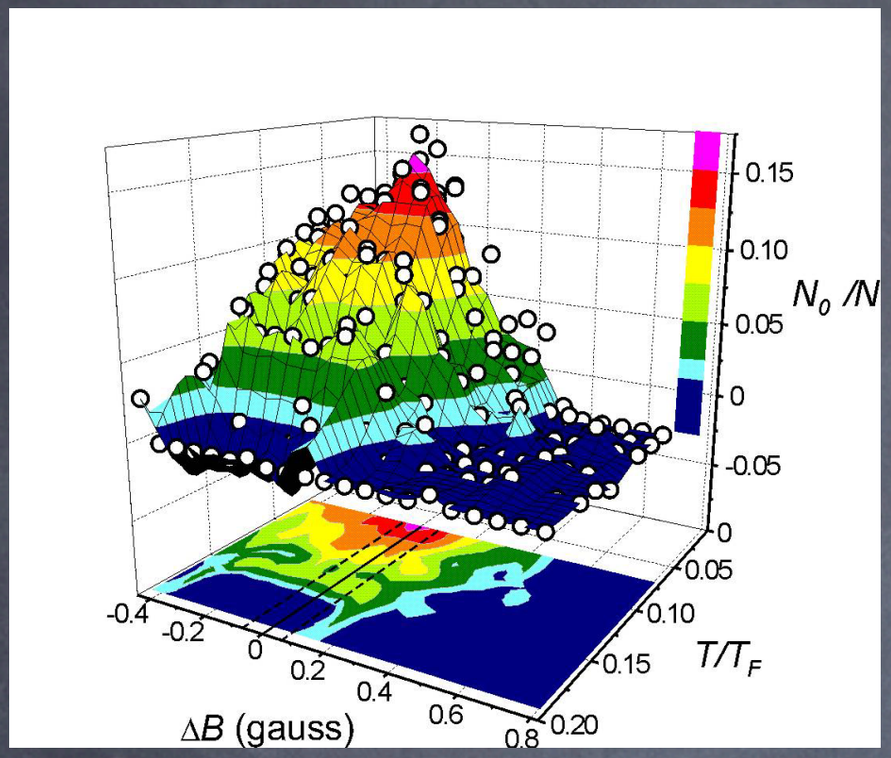
Macroscopic QM.

Microtraps

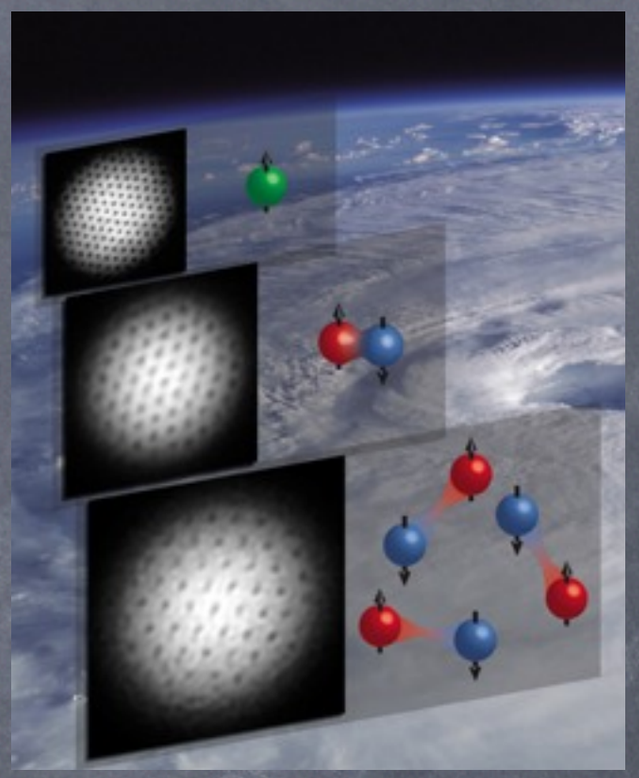
QM "microscope"

Greiner Lab, Harvard 2009

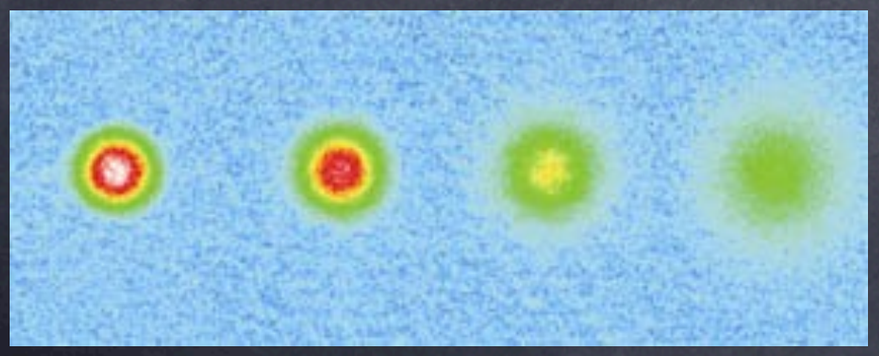
BEC-BCS cross-over



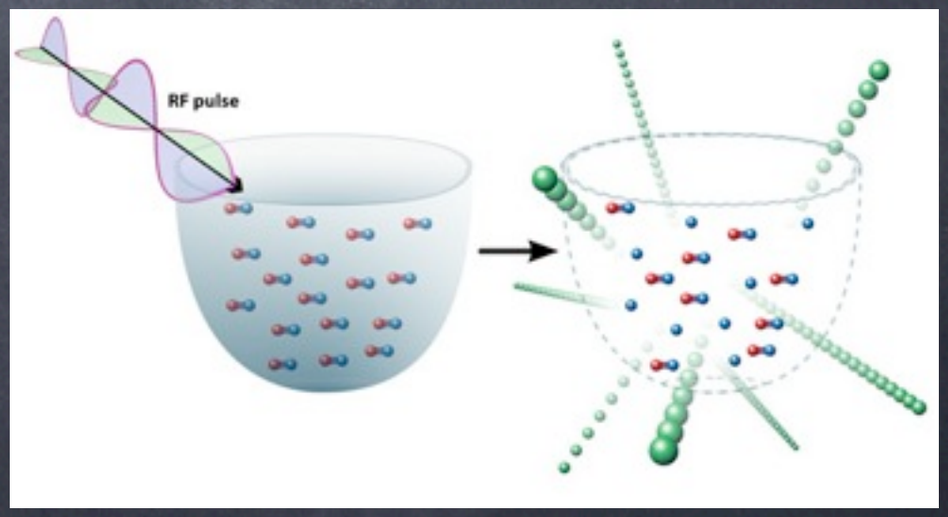
Rotation



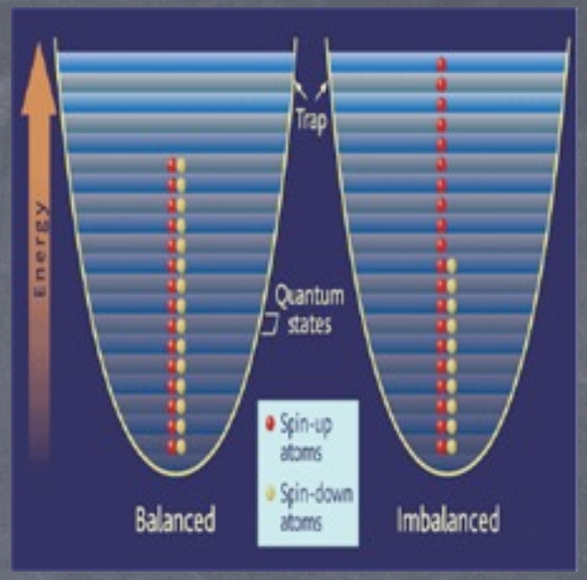
Expansion experiments

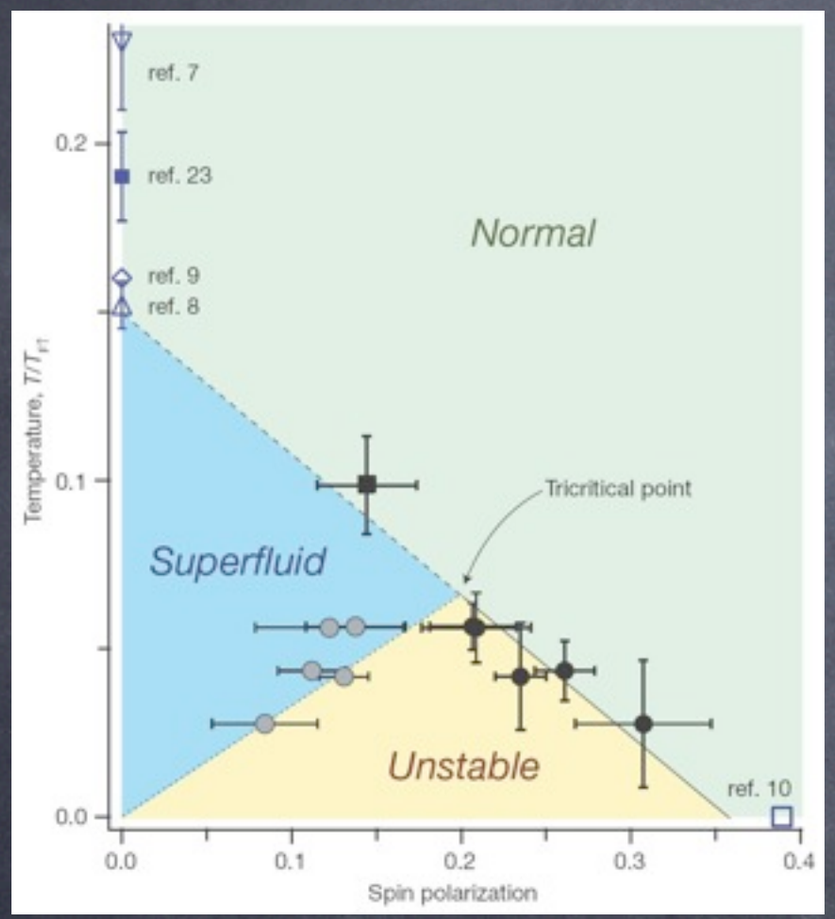


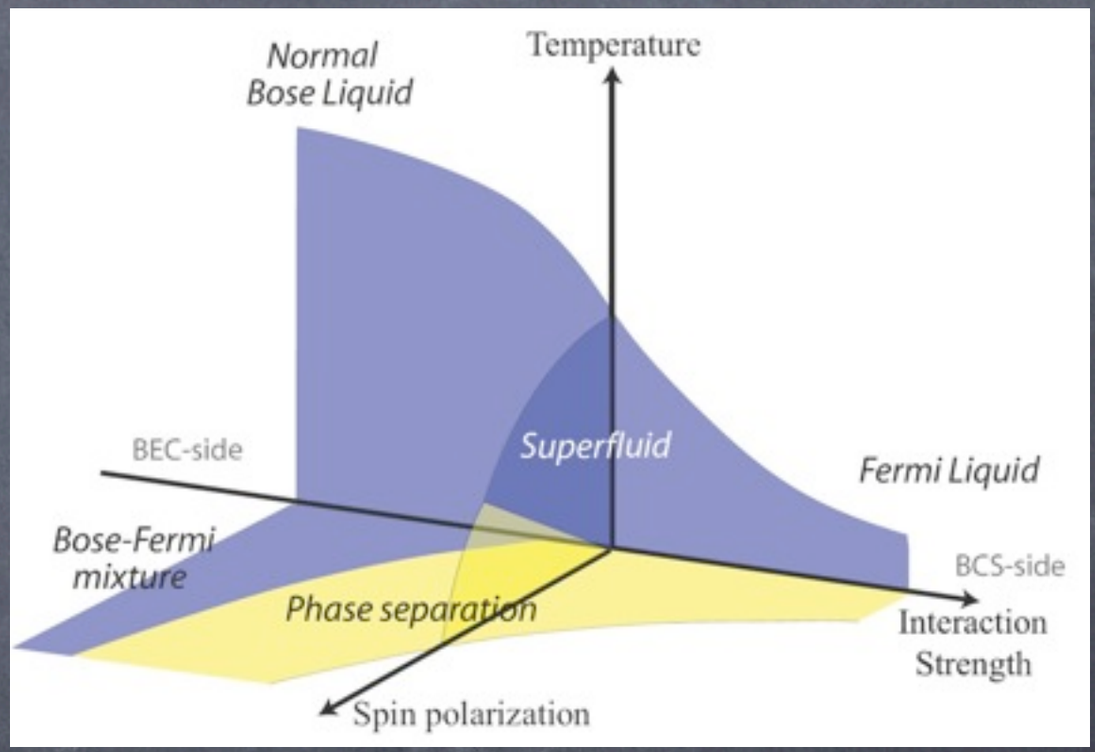
Bragg spectroscopy



Polarization: $P = \dfrac{N_\uparrow - N_\downarrow}{N_\uparrow + N_\downarrow} > 1$

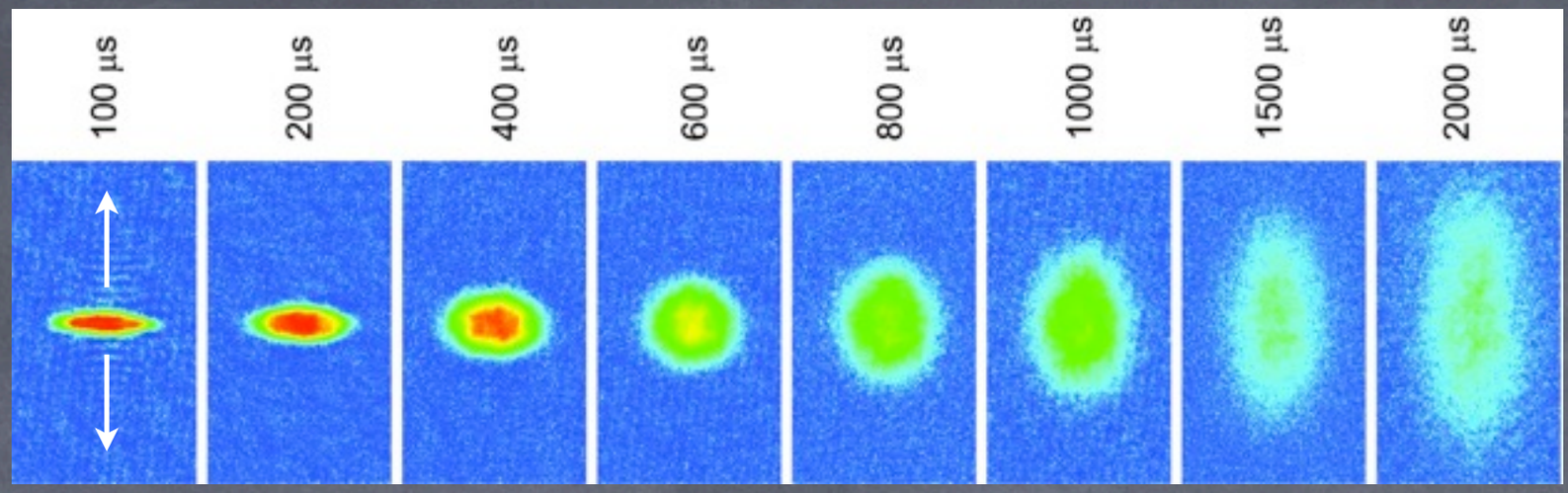






Hydrodynamic Expansion

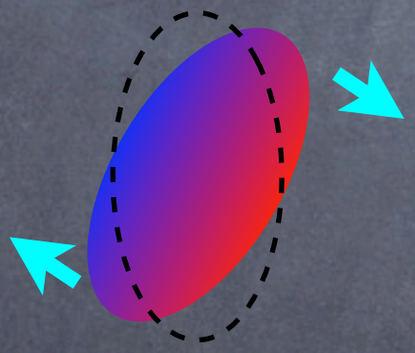
$$\rho \partial_t \mathbf{u} = -\nabla P$$

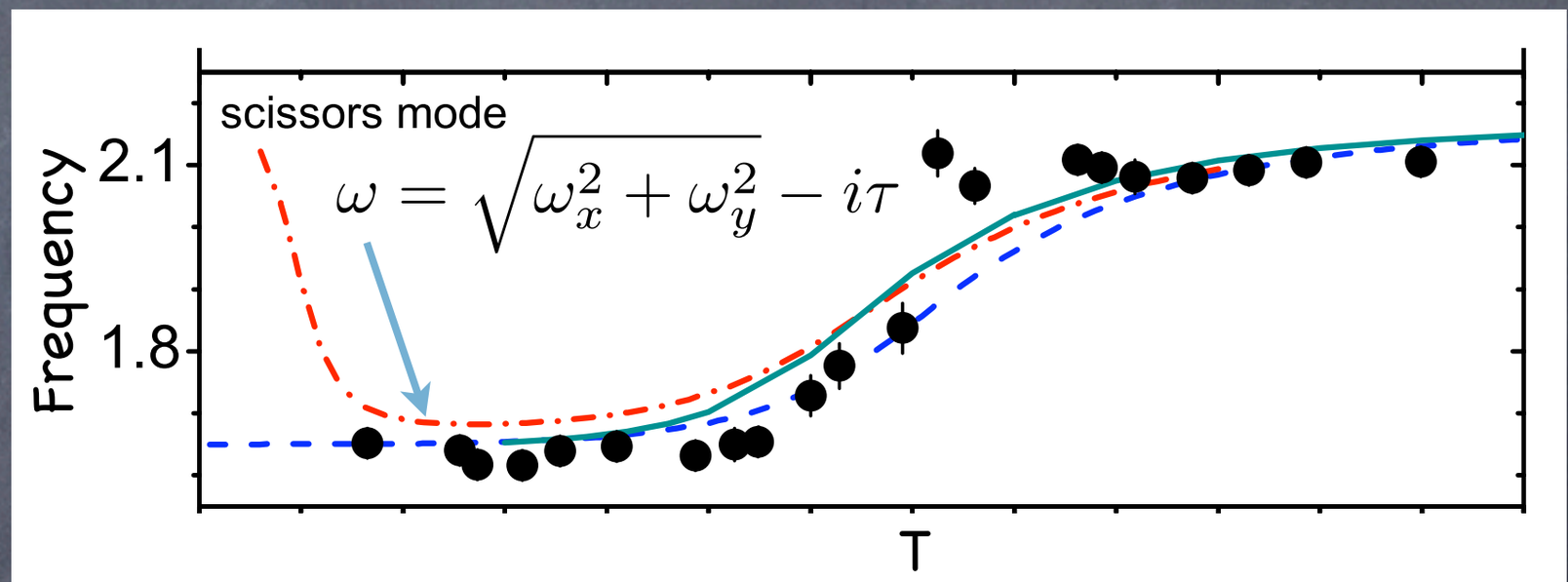


Thomas Lab, Duke 2004

Collective Modes

Scissors Mode





Grimm Lab, Innsbruck 2009

"Perfect" Fluid
10000 thinner than air

Ideal and Viscous Fluids

Hydrodynamics (Low energy eff. theory)

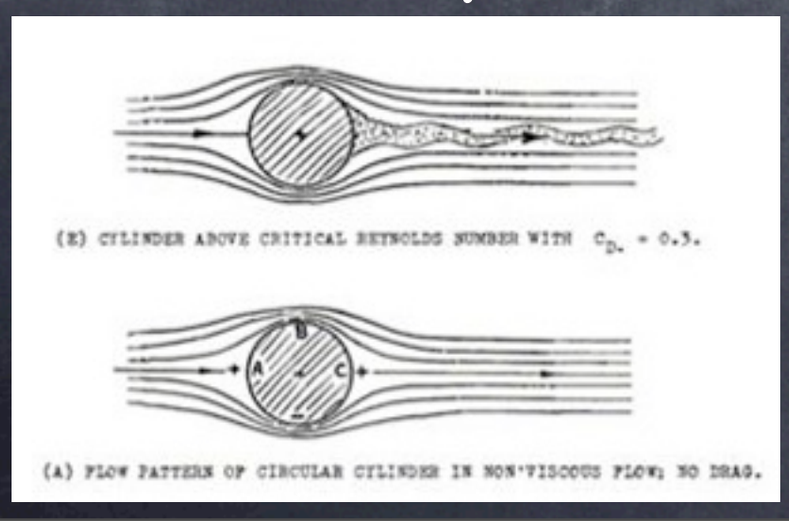
- Continuity: $\partial_t \rho + \nabla(\rho \mathbf{v}) = 0$
- Euler: $\partial_t(\rho v_i) + \partial_k \Pi_{ik} = 0$

$$\Pi_{ik} = P\delta_{ik} + \rho v_i v_k - \eta\left(\partial_i v_j - \partial_j v_i - \frac{2}{3}\delta_{ij}\nabla\cdot\mathbf{v}\right) - \zeta\delta_{ij}(\nabla\mathbf{v})$$

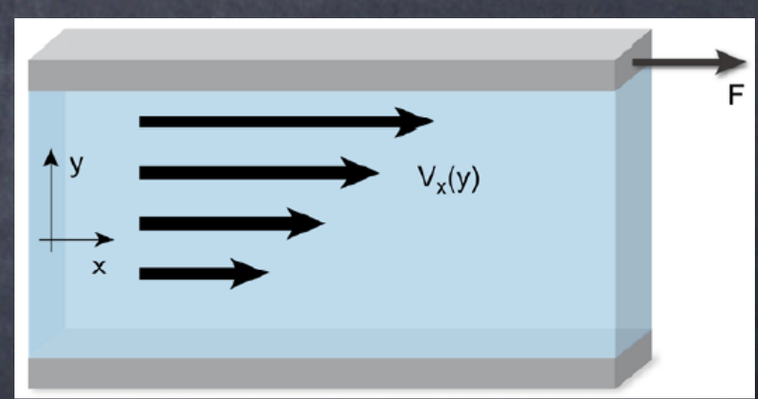
Ideal Fluid

Dissipative

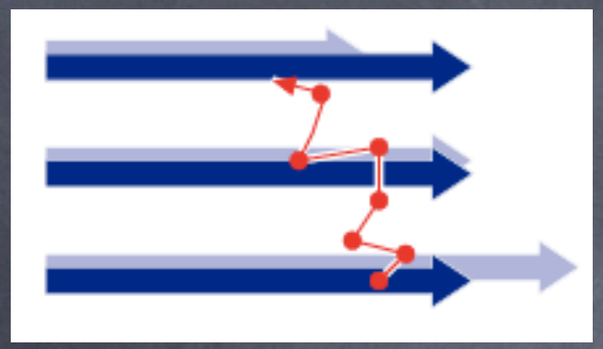
Shear Viscosity: "Friction"



$$\frac{F}{A} = \eta\partial_y v_x$$



Kinetic Picture

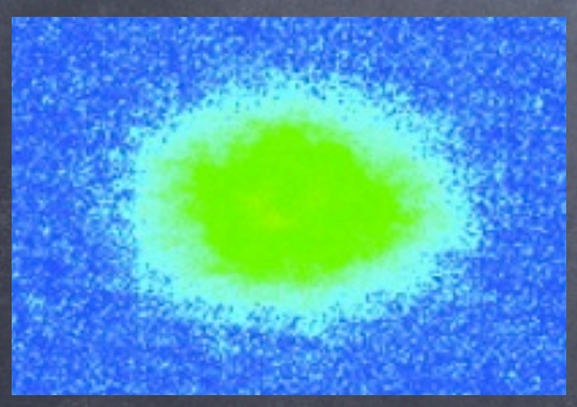


Low collision rate → Large Viscosity

High collision rate → Small Viscosity

Small Viscosity means strong interactions

Cold Gases



T≈10^{-7}K

Coldest place on planet

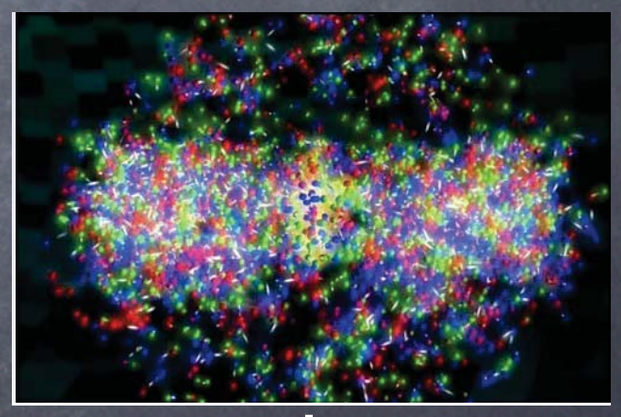
$\eta \sim 10^{-15} Pa \cdot s$

Liquid Helium

T≈1K

$\eta \sim 10^{-6} Pa \cdot s$

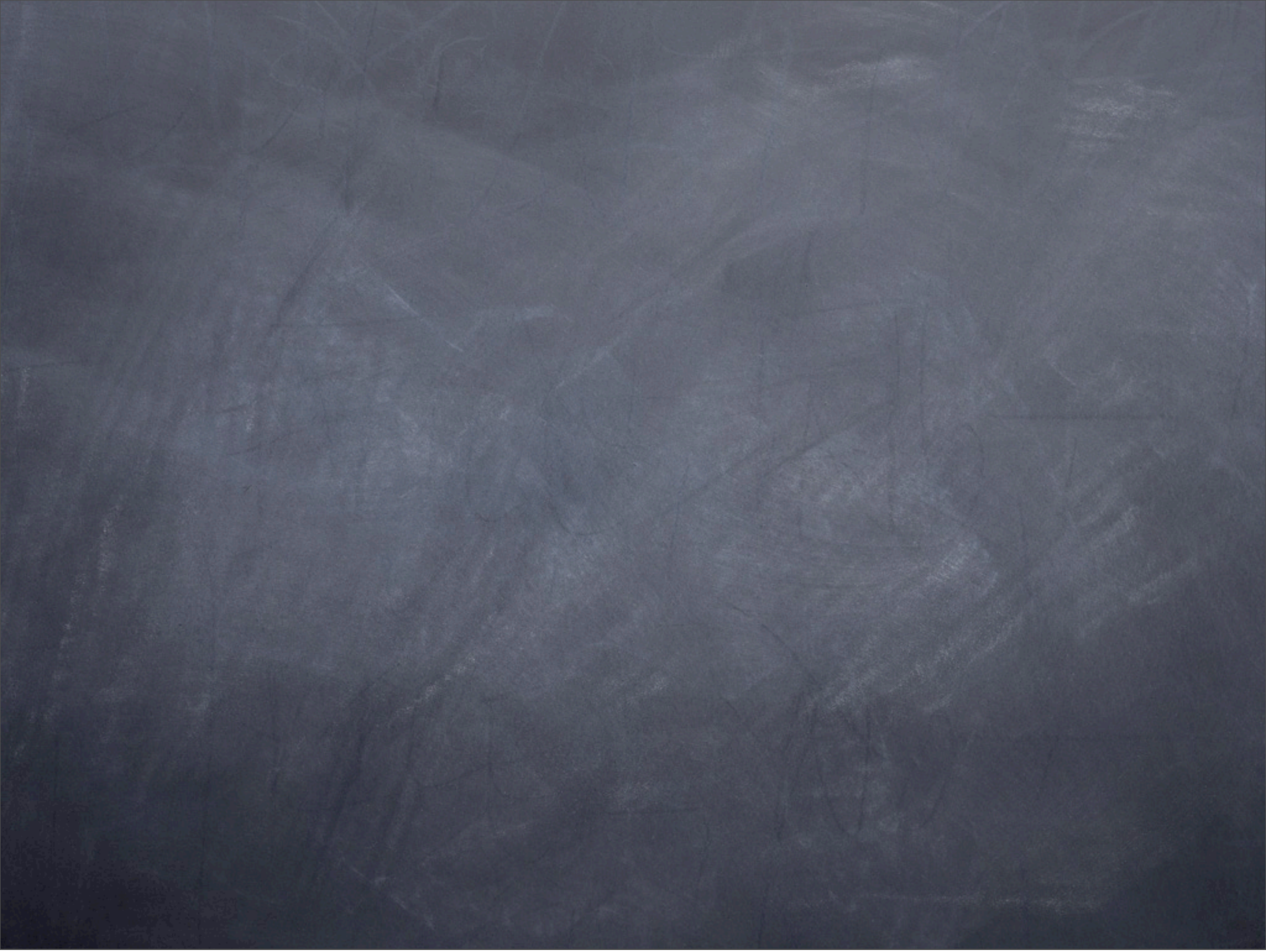
Quark-Gluon Plasma



T≈10^{12}K

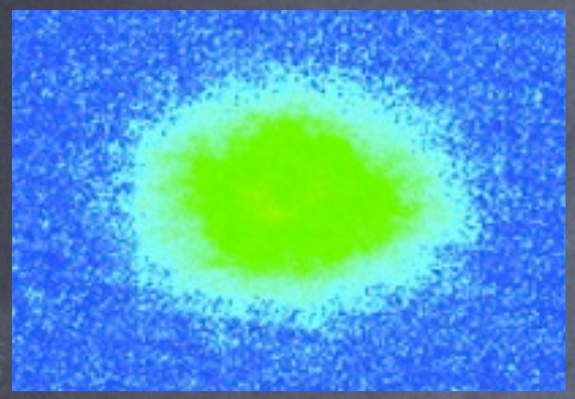
Hottest place on planet

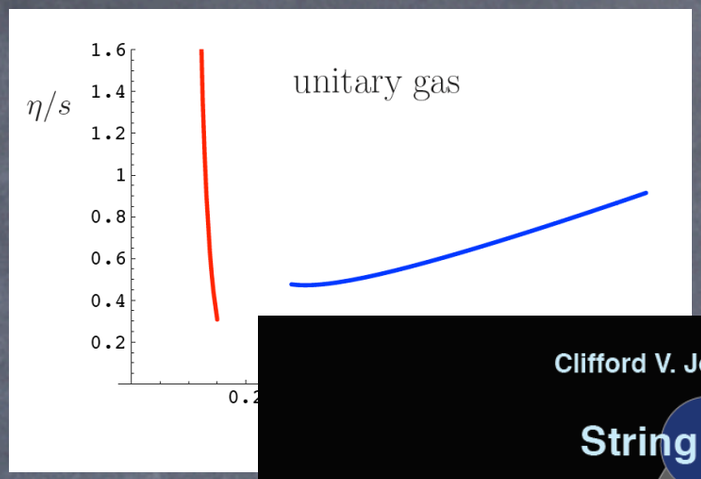
$\eta \sim 10^{11} Pa \cdot s$

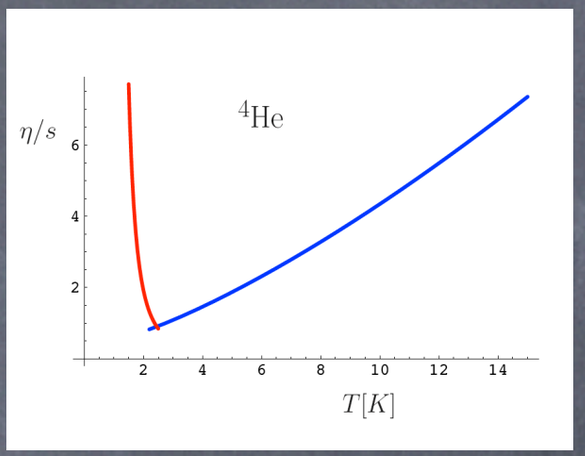


String-theory & AdS/CFT: $\frac{\eta}{s} \geq \frac{\hbar}{4\pi k_B}$

Cold Gases $T \approx 10^{-7}K$

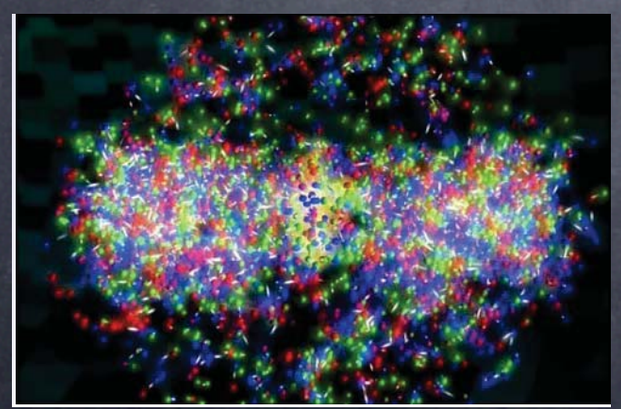


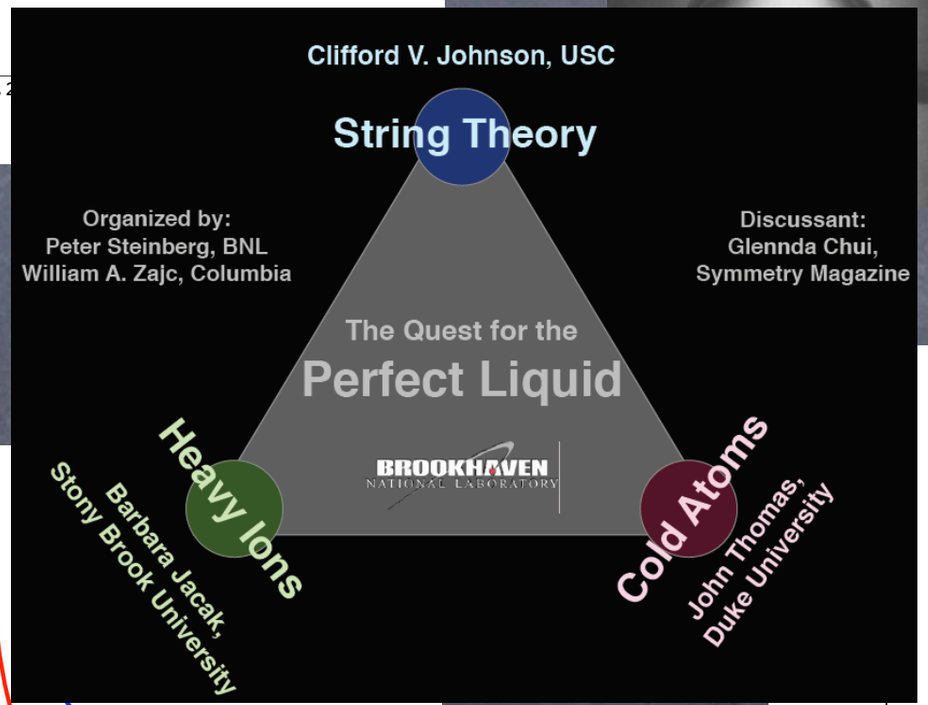


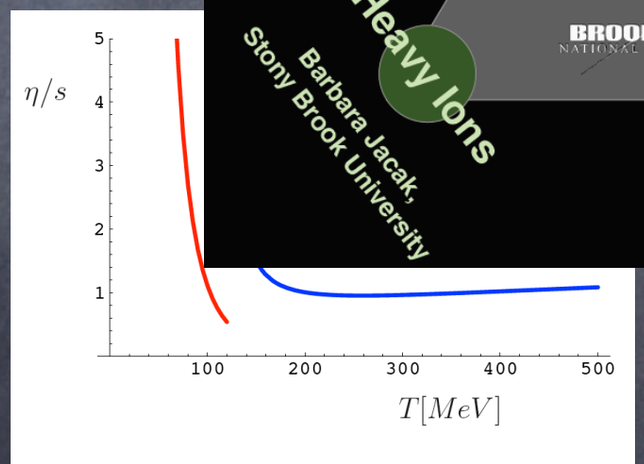


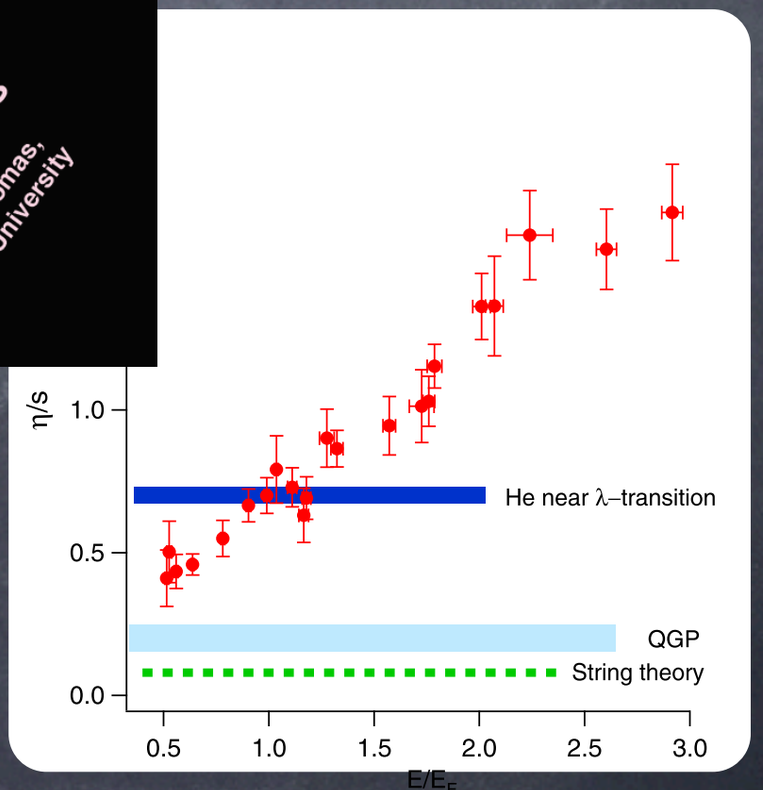
Liquid Helium $T \approx 1K$

Quark-Gluon Plasma $T \approx 10^{12}K$



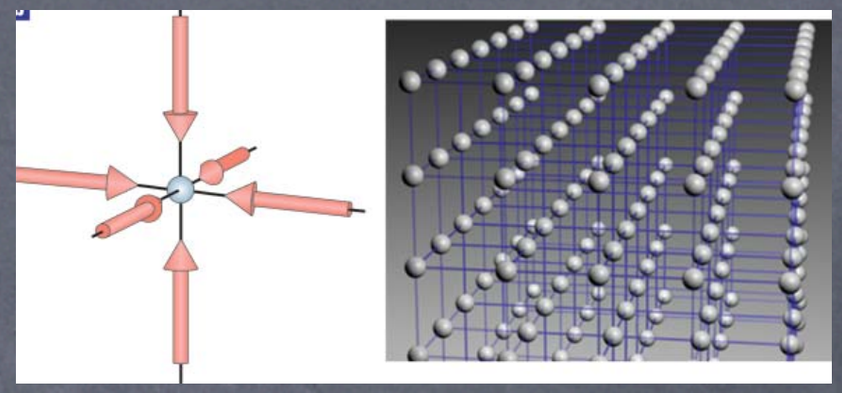




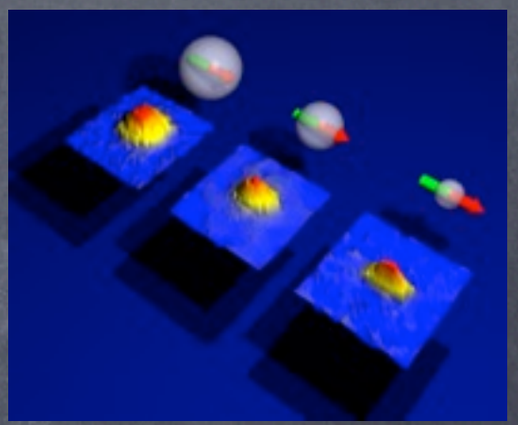


Perspectives

- Optical lattices. Spin physics, Hubbard model ...



- Dipolar molecules/atoms. New phases ..



- Polarized systems ....

- Bose-Fermi mixtures, multicomponent systems, ..

- Transport, non-equil.