There's life in them old BEC's yet...

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Intro

- for BEC dynamics, Gross-Pitaevski mean field breaks down when:
  - Supersonic $\hbar k > m v_s$
  - Small scale $\lesssim \xi$
  - Density correlations relevant
- The problem with full quantum dynamics : Hilbert space complexity
- Why not path integral Monte Carlo?
- A partial solution: phase-space dynamics

Complete Quantum Dynamics

$$\widehat{H} = \int d^3x \left[\widehat{\Psi}^\dagger(x) H_{\rm sp}(x) \widehat{\Psi}(x) + \frac{g}{2} \widehat{\Psi}^\dagger(x)^2 \widehat{\Psi}(x)^2 \right]$$

Gross-Pitaevskii equation (GP) is:

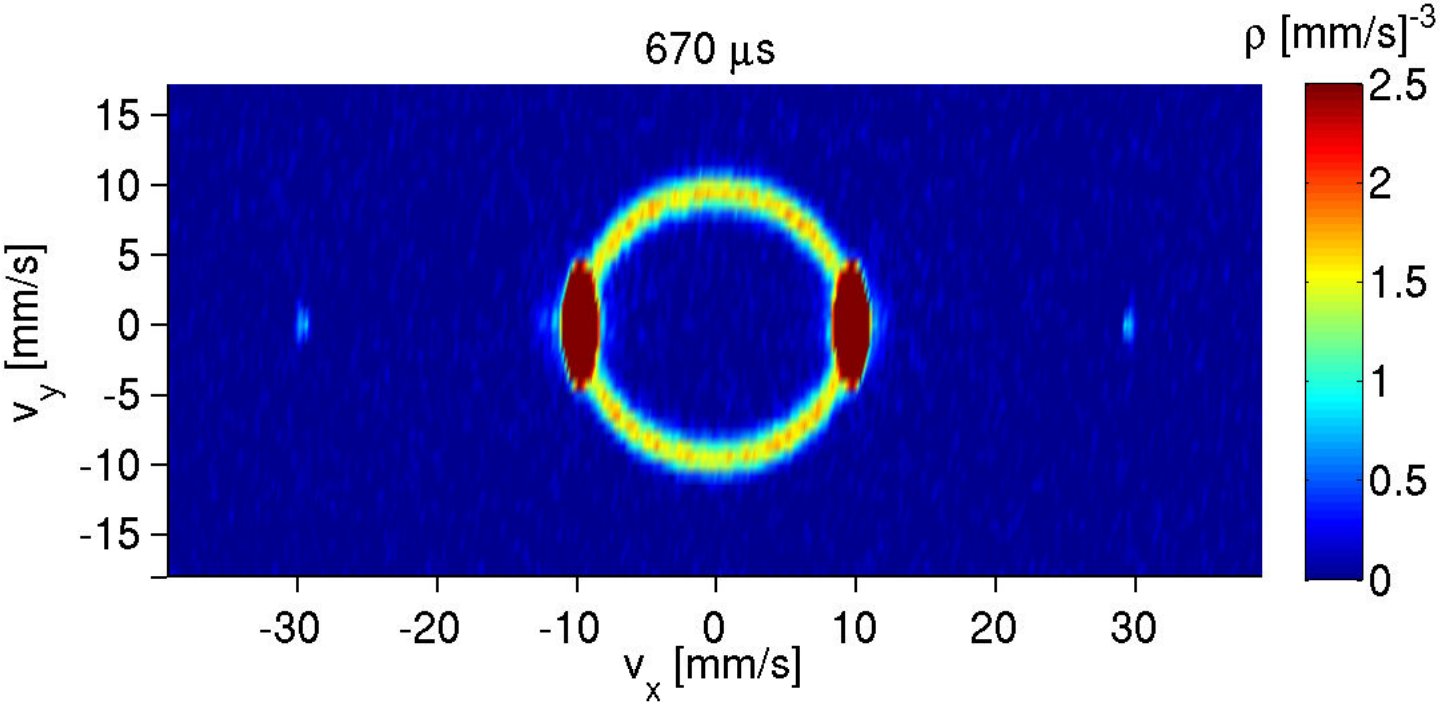
$$i\hbar \frac{\partial \psi(x)}{\partial t} = \left[H_{\rm sp}(x) - ig|\psi(x)|^2 \right] \psi(x)$$

Complete quantum dynamics (positive-P) = [GP + noise] $\times 2$

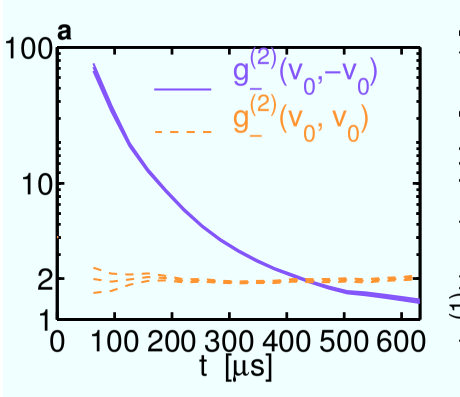
$$\begin{aligned} i\hbar \frac{\partial \psi_1(x)}{\partial t} &= \left[H_{\rm sp}(x) - ig n(x) + i\sqrt{ig}\, \xi_1(x,t) \right] \psi_1(x) \\ i\hbar \frac{\partial \psi_2(x)}{\partial t} &= \left[H_{\rm sp}(x) - ig n(x)^* - \sqrt{ig}\, \xi_2(x,t) \right] \psi_2(x) \\ n(x) &= \psi_1(x) \psi_2(x)^* \end{aligned}$$

BEC Collision

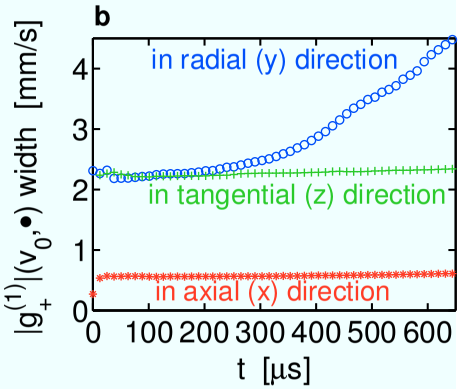
Density slice in k-space along collision



density correlations



phase grain size in the halo



Similar to Na collisions at MIT (Vogels, Xu, Ketterle PRL, 89, 020401).

Atomic superradiance

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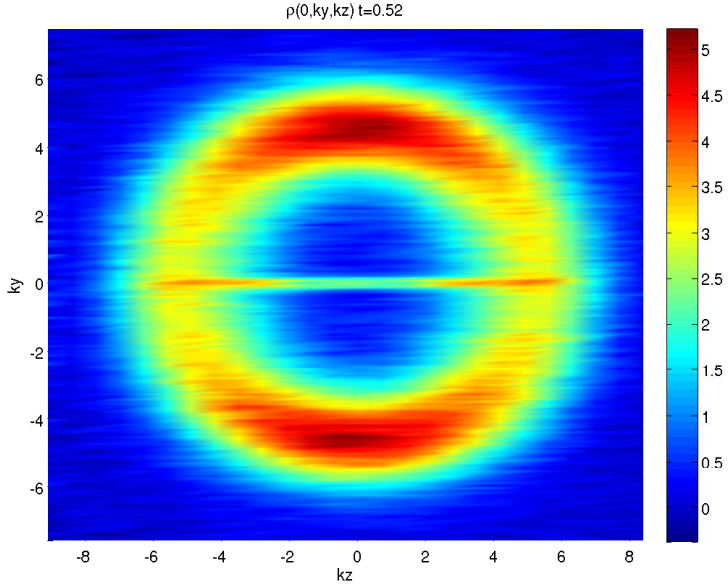
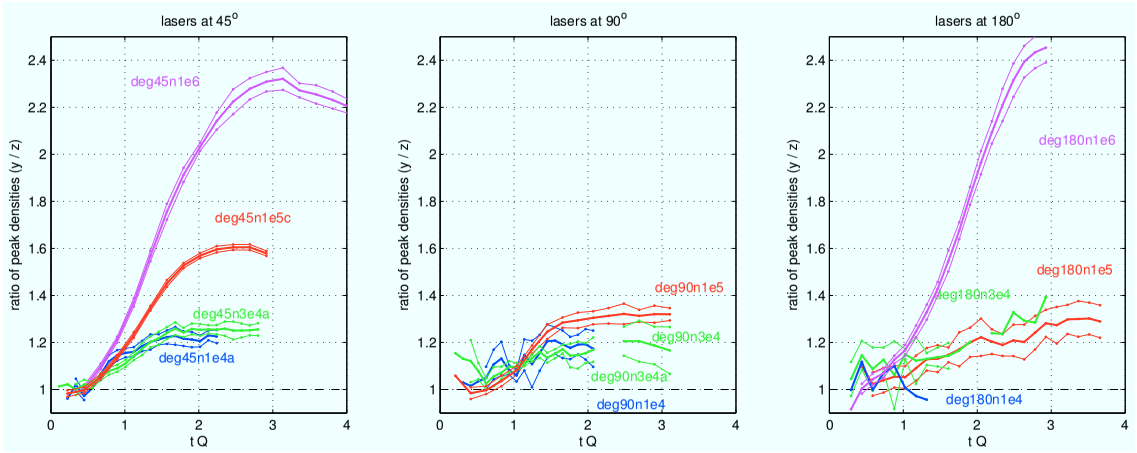
Density slice in k-space ⊥ to collision



anisotropy as a function of:

density (blue= small purple=large)

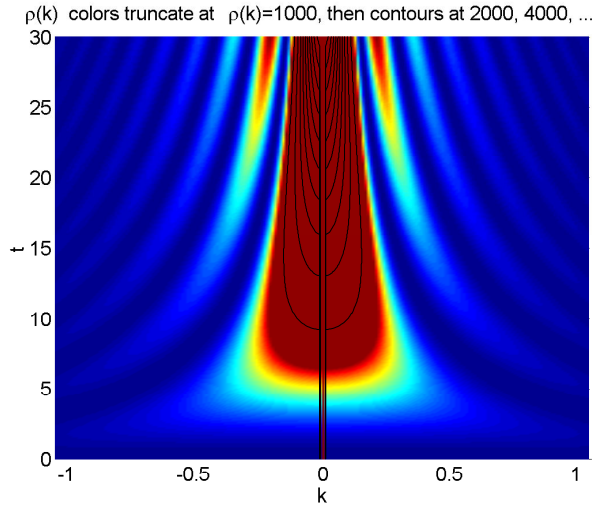
and velocity(left = slow, right=fast)



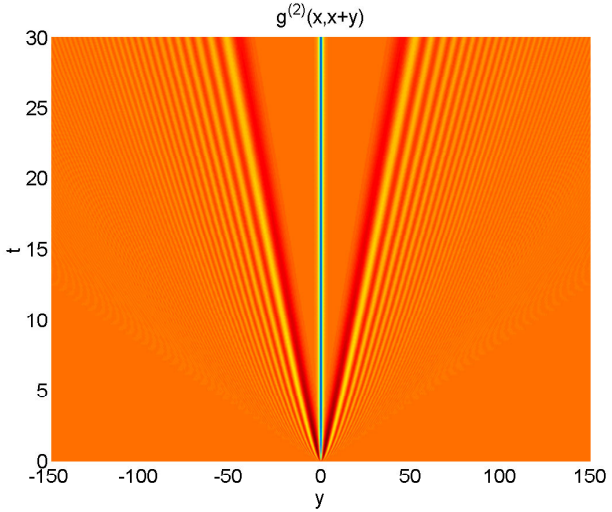
As per He* collisions at Palaiseau (C. Westbrook *et al.*)

Correlations after a quench in 1D and 2D

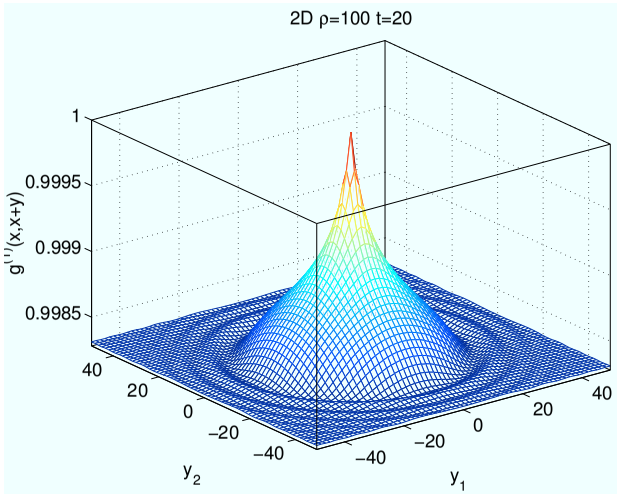
1D k-space density



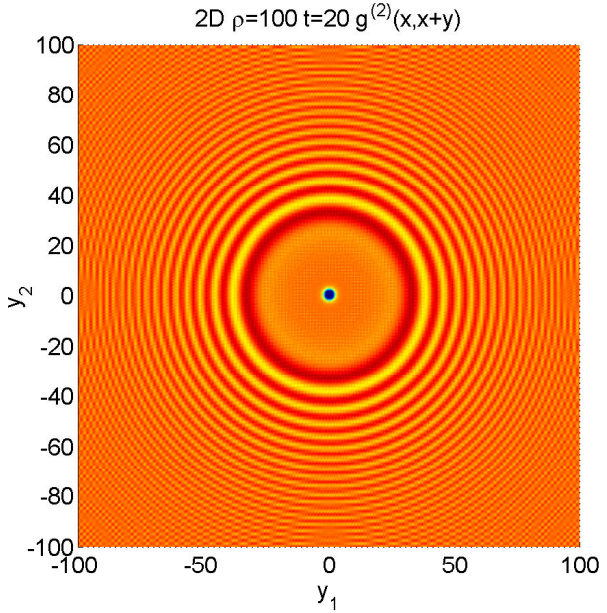
1D density-density correlations



2D coherence



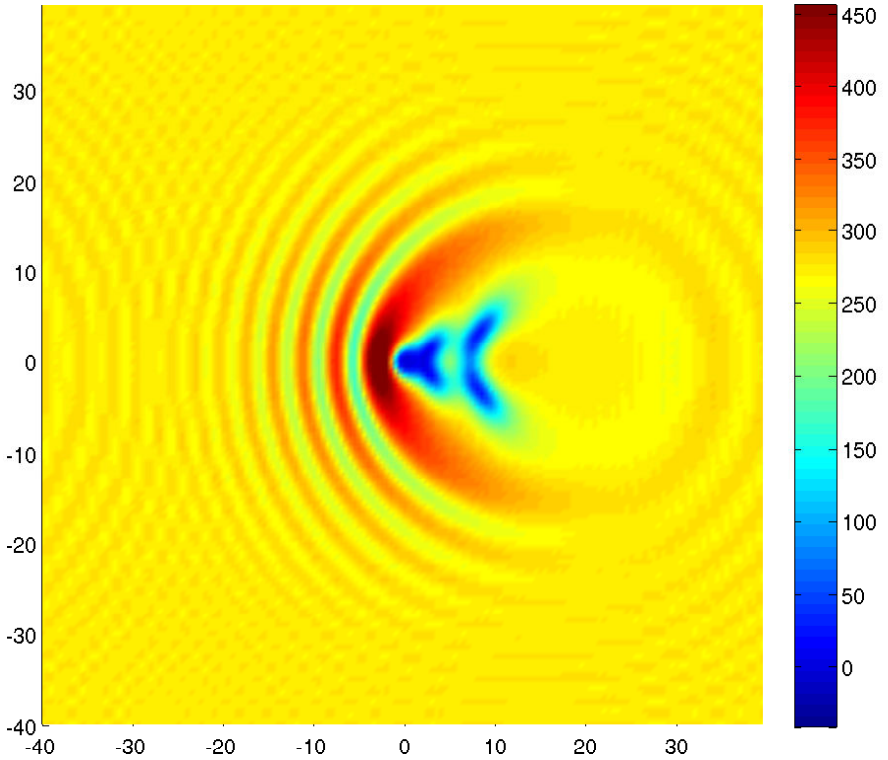
2D density-density correlations



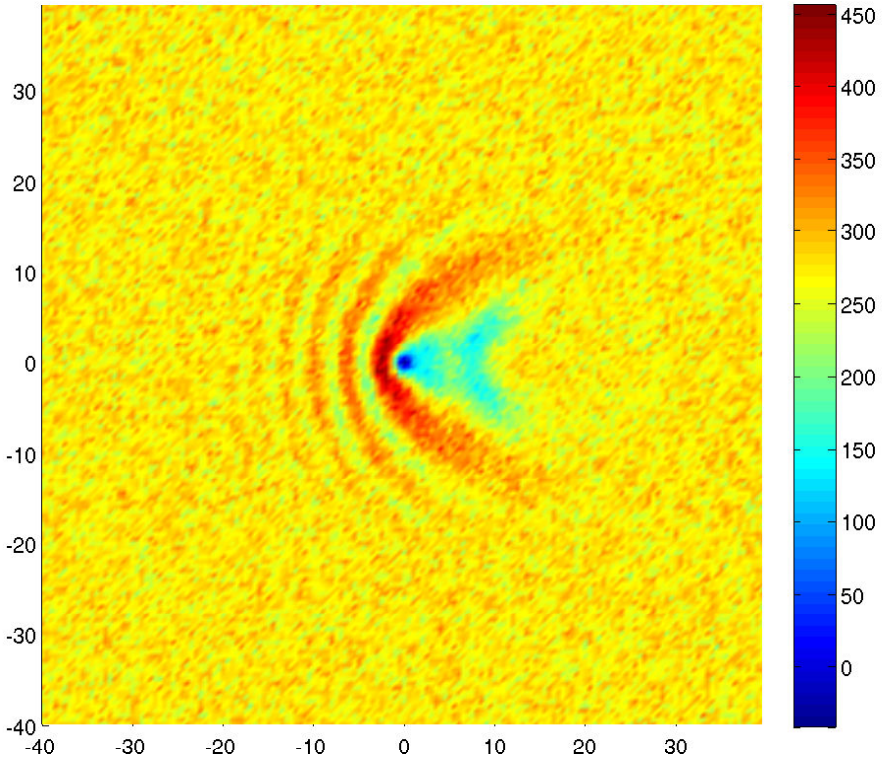
Supersonic flow around obstacle

Obstacle in center, particle density shown

mean field (GP)



truncated Wigner (close to full QD)



Similar to experiments at JILA (E Cornell *et al.*)