Freezing of spinor dynamics in an ultracold Bose gas via microwave dressing

Zhifan Zhou[1], Madison Anderson[1], Don Fahey[1], Jonathan Wrubel[2], Paul Lett[1]

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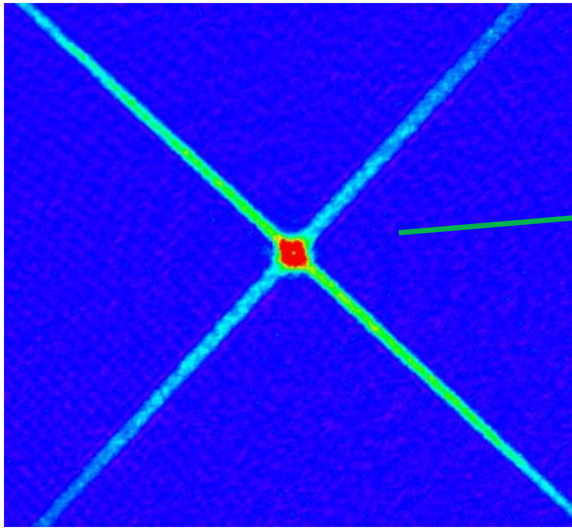
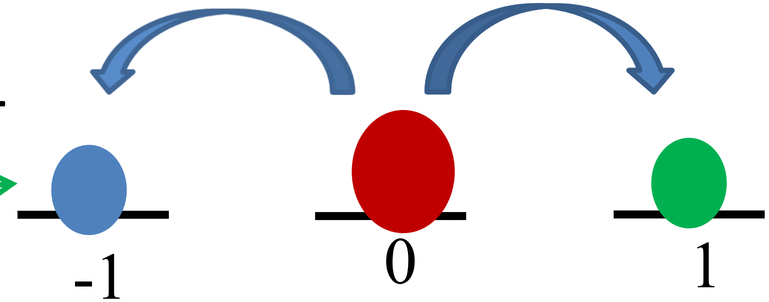
Spinor dynamics in optical trap: introduction



^{23}Na, $3S_{1/2}$, F=1



$$\theta = \theta_+ + \theta_- - 2\,\theta_0$$

$$m = \rho_+ - \rho_-$$

$$c = c_2\,\bar{n}$$

External term

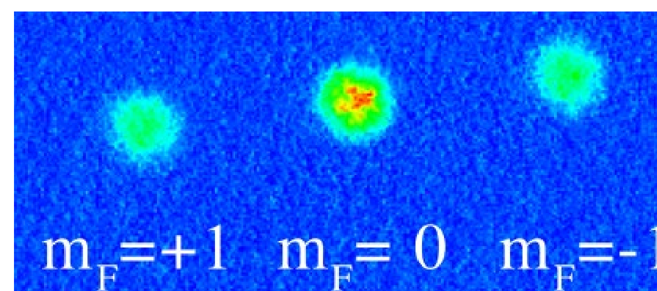
Collisional term

$$E = q\,(1-\rho_0) + c\rho_0[(1-\rho_0) + \sqrt{(1-\rho_0)^2 - m^2}\,cos\theta]$$

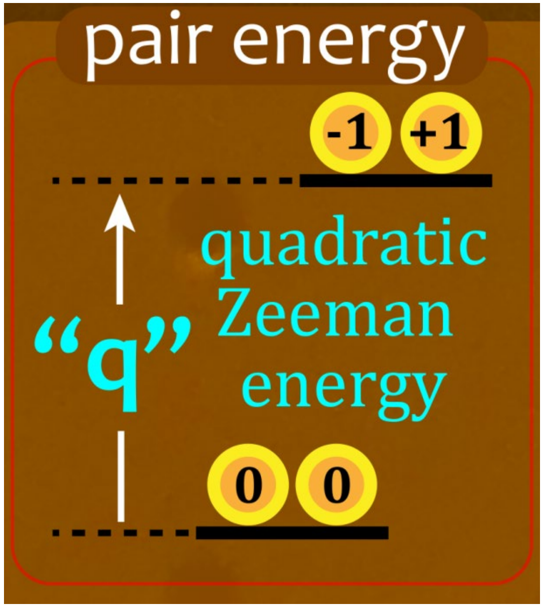
$$\dot{\rho}_0 = -(2/\hbar)\partial E/\partial\theta$$

$$\dot{\theta} = (2/\hbar)\partial E/\partial\rho_0.$$

Trap release, Stern-Gerlach pulse,
time-of-flight expansion,
absorption imaging.



Dynamical evolving in phase space



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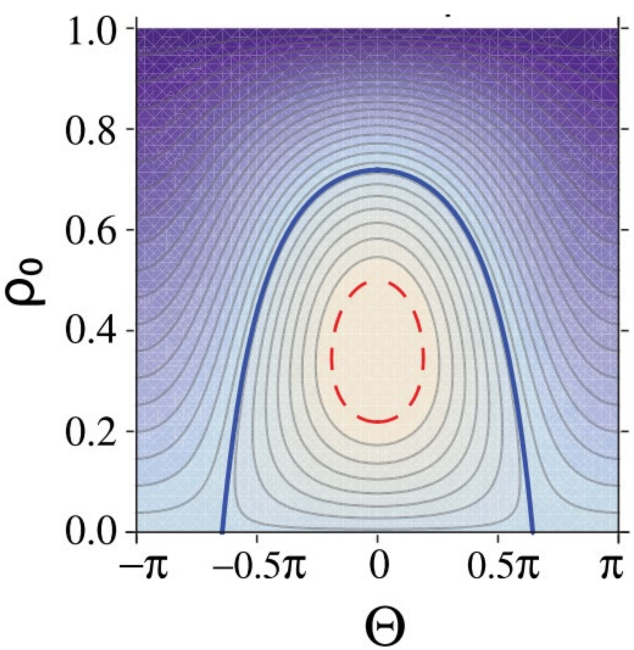
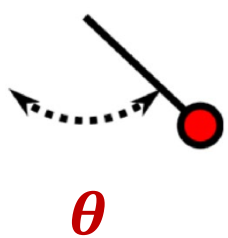
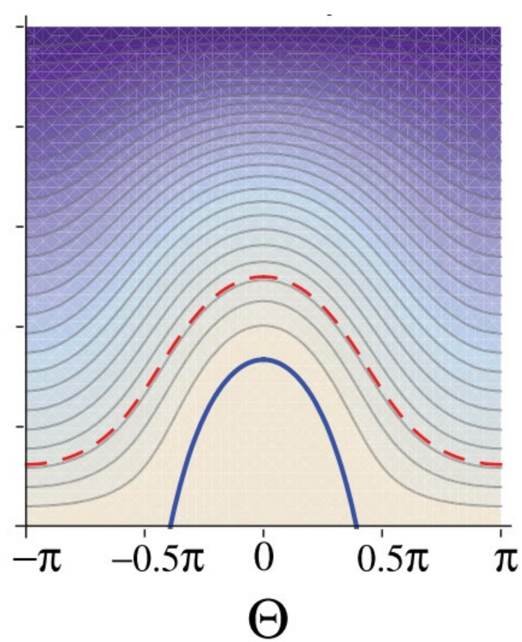
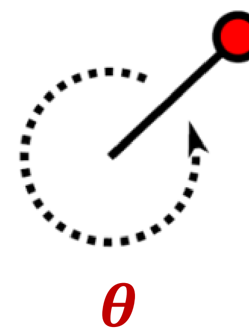


B = 26 μT



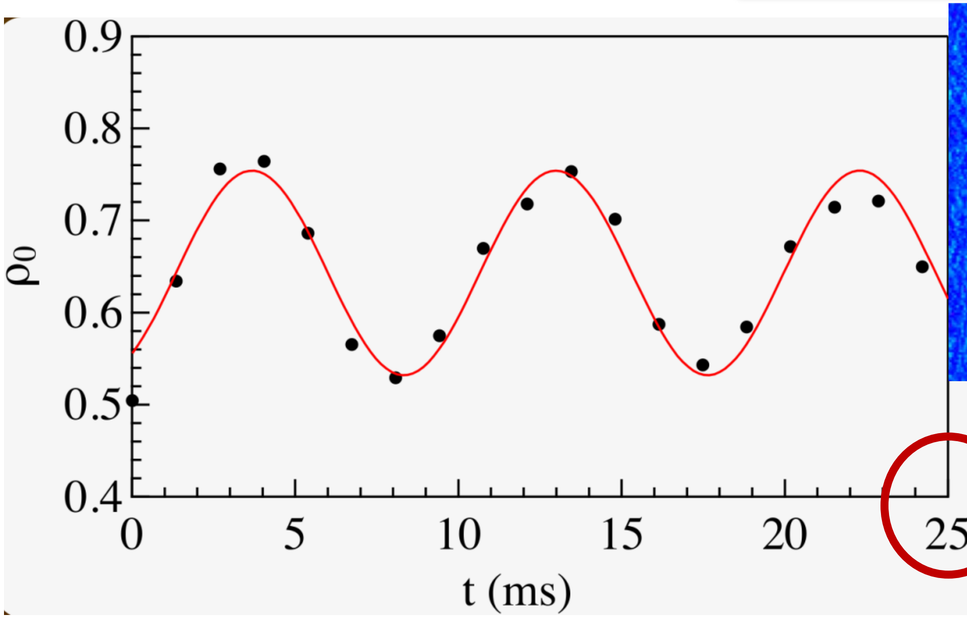


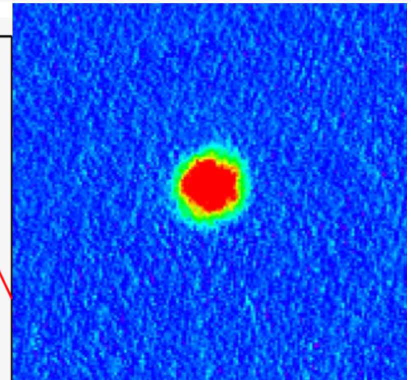
B = 40 μT



Density-dependent dynamics

BEC:



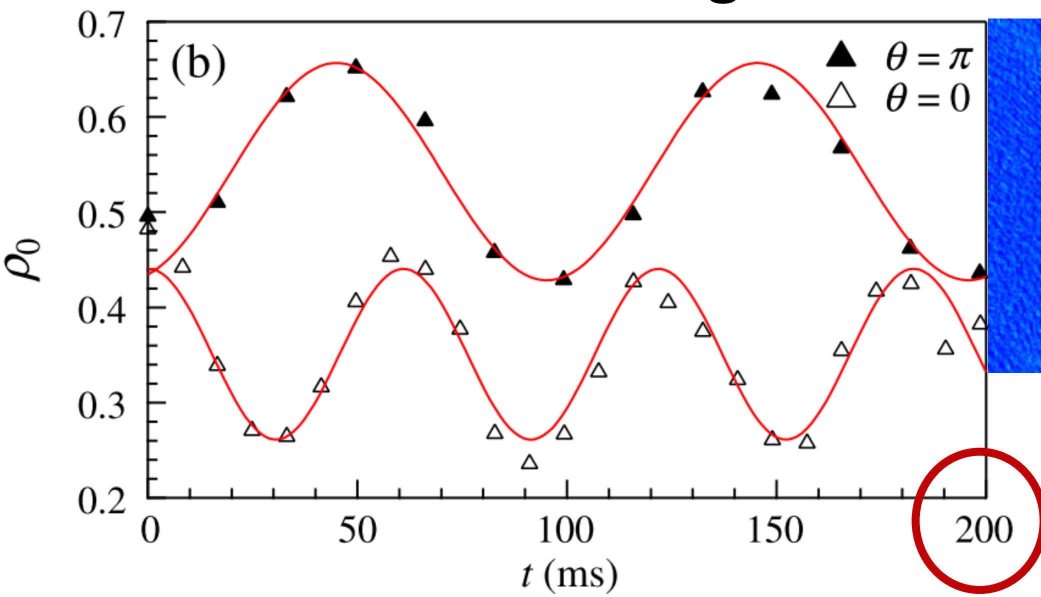


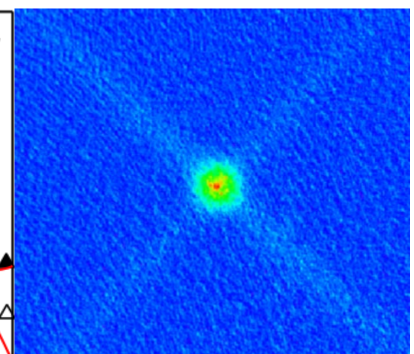
Particle density in BEC is roughly 10 times higher than in thermal gas.

$$c = c_2\,\bar{n}$$

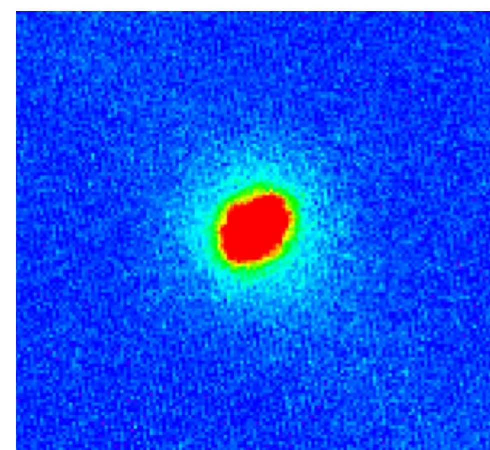
$$E = q\,(1-\rho_0) + c\rho_0[(1-\rho_0) + \sqrt{(1-\rho_0)^2 - m^2}\,cos\theta]$$

Thermal gas:

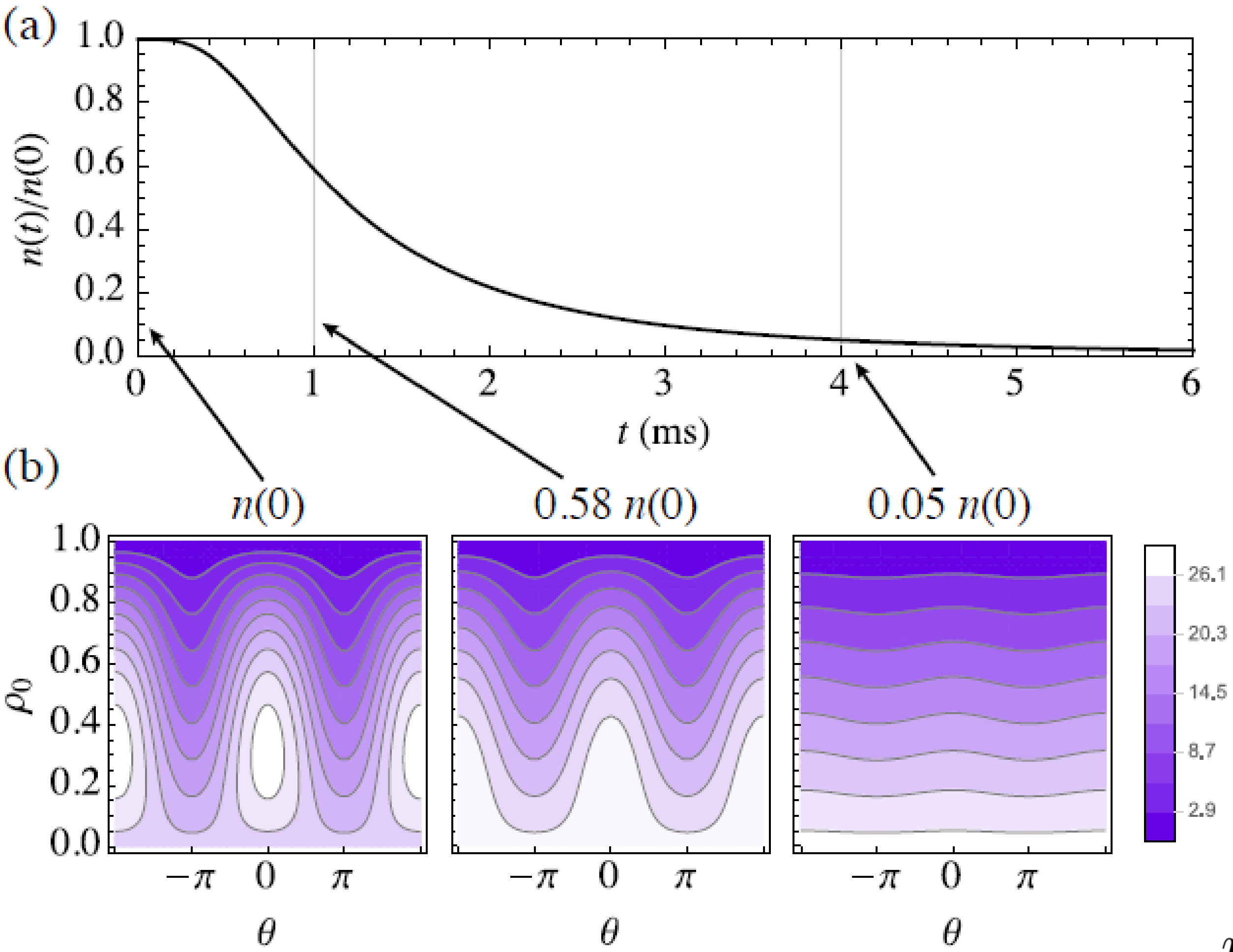




BEC/thermal mixture?



Trap release, density change during time-of-flight



Key to population oscillation freezing: q≫c

$$\dot{\rho}_0 = -(2/\hbar)\partial E/\partial\theta$$

$$\dot{\theta} = (2/\hbar)\partial E/\partial\rho_0.$$

$$\theta = \theta_+ + \theta_- - 2\,\theta_0$$

$$m = \rho_+ - \rho_-$$

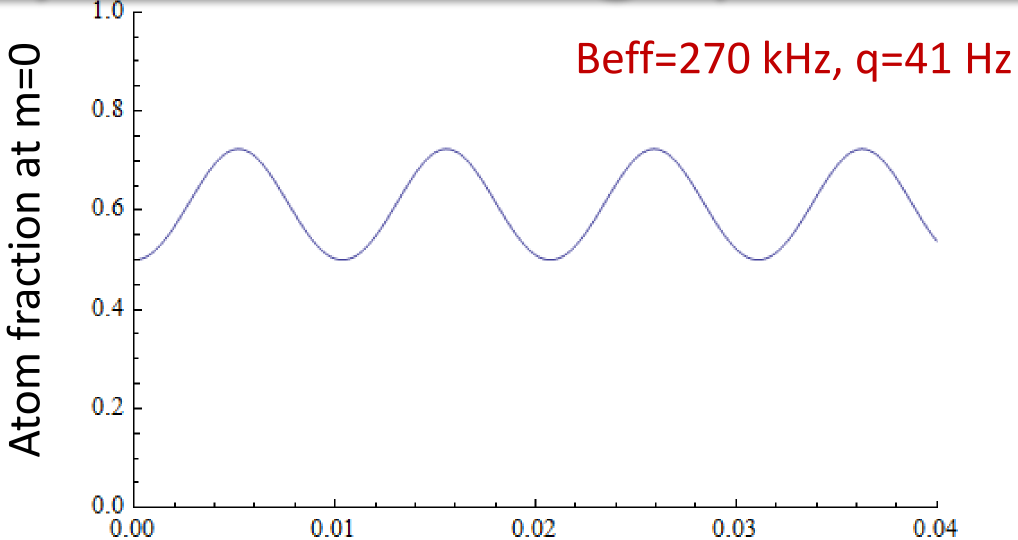
$$c = c_2\,\bar{n}$$

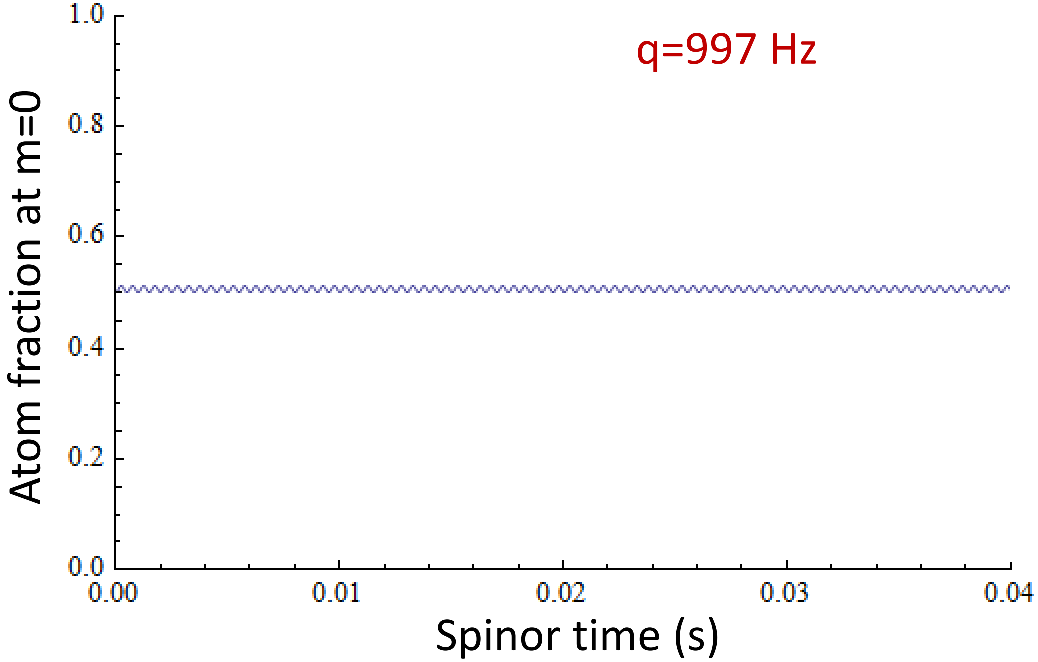
External term

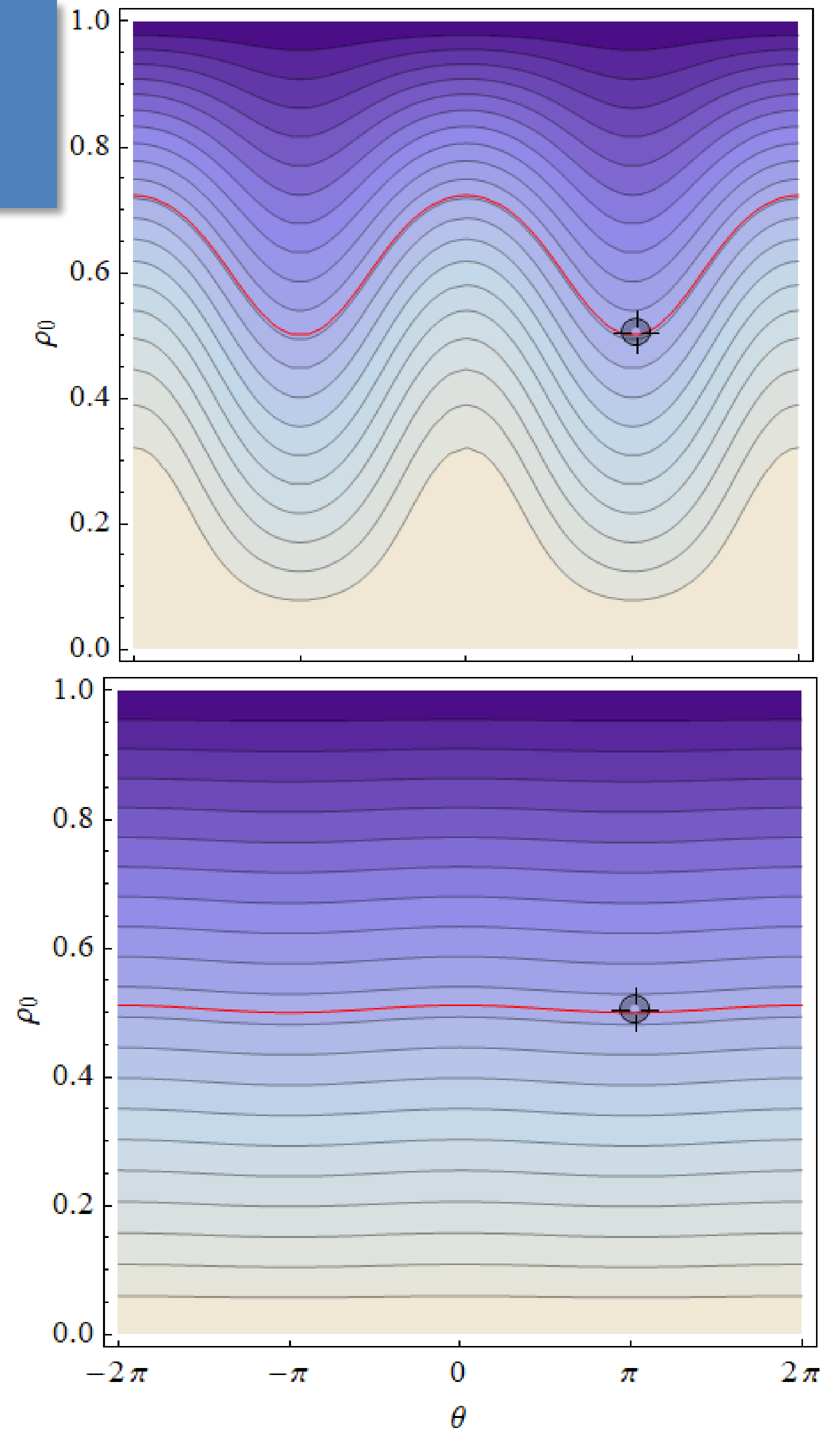
Collisional term

$$E = q\,(1-\rho_0) + c\rho_0[(1-\rho_0) + \sqrt{(1-\rho_0)^2 - m^2}\,cos\theta]$$

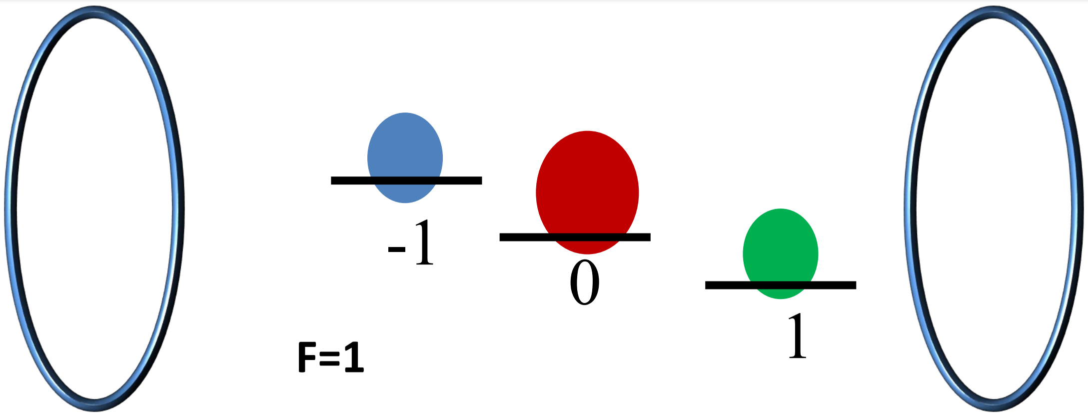
Simulation population dynamics freezing: q≫c





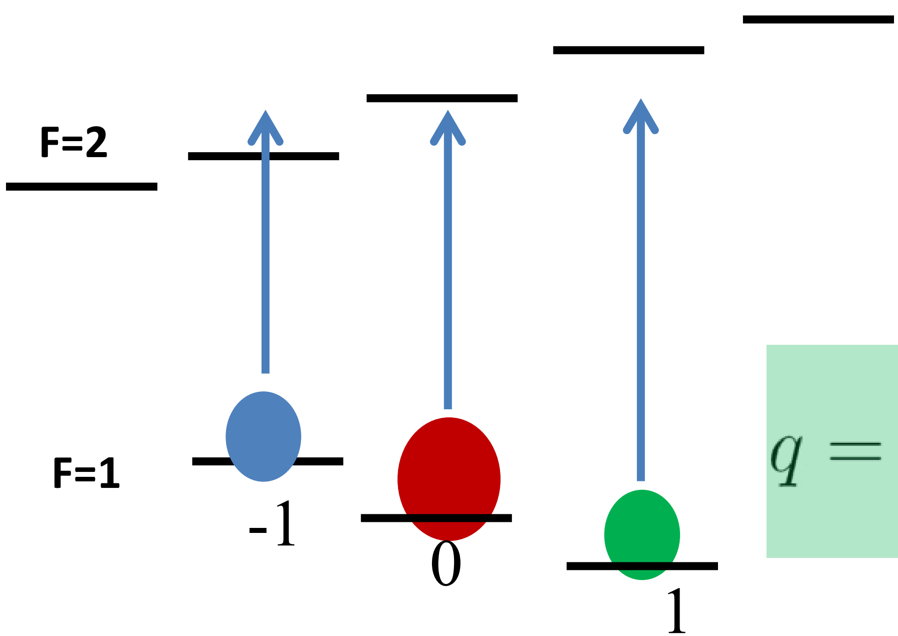


Magnetic field vs microwave dressing: large q



Linear order is cancelled,
Quadratic Zeeman energy is left.

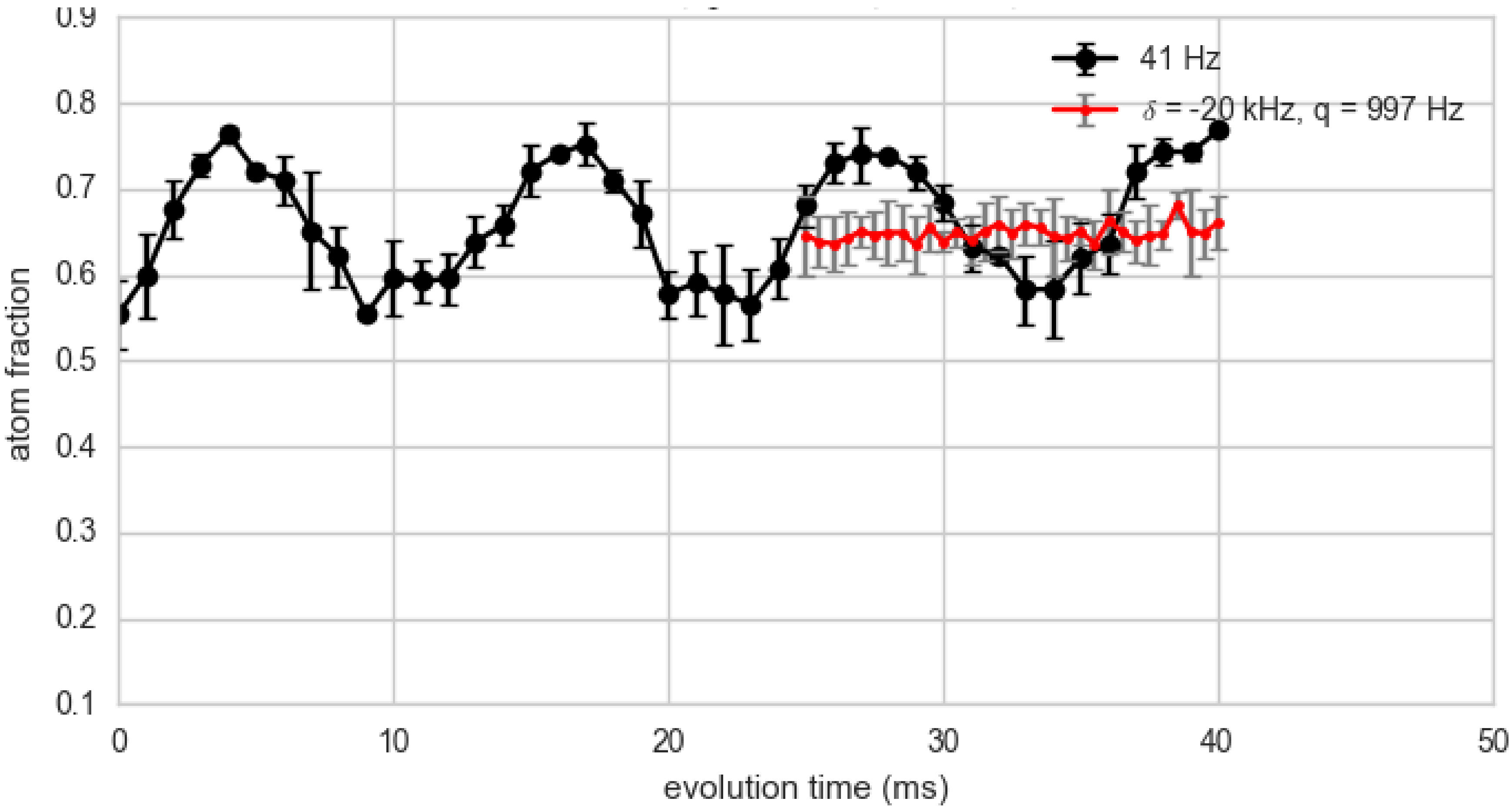
$$q = h\ \left(277\ \mathrm{Hz/G^2}\right)\ B^2$$



$$q = -\hbar\,\frac{\Omega^2}{\Delta_\mu}$$

MW dressing:
Fast switch on/off
Flexible direction +/-

Freezing the spinor dynamics: experiment



The freezing/evolution time, in principle, is limited by the optical trap lifetime.

Interrogate phase running situation, state-mixing atom loss.

Conclusion

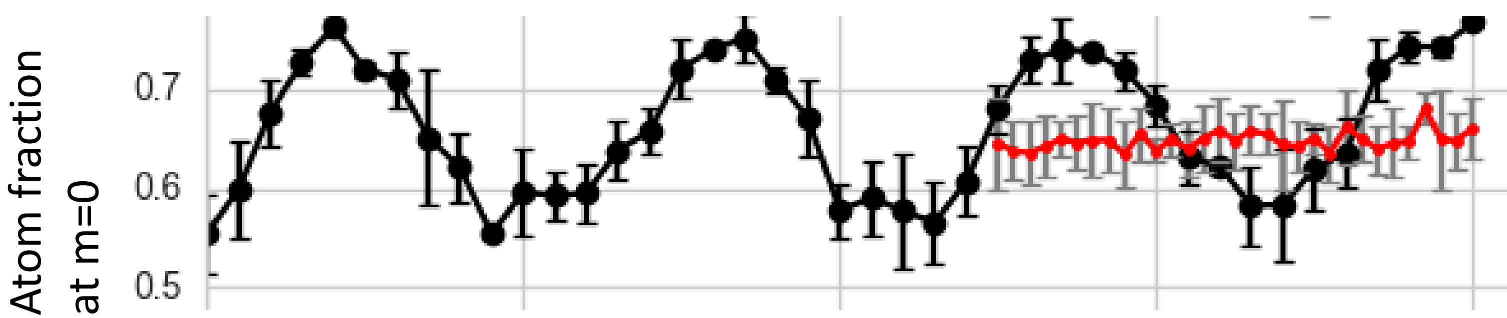
- Analyze density-dependent spinor dynamics
- Freeze the population dynamics while the phase running gets faster via q≫c
- Experimentally demonstrate the freezing of the population dynamics via microwave dressing

External term

Collisional term

$c = c_2\,\bar{n}$

$$E = q\,(1-\rho_0) + c\rho_0[(1-\rho_0) + \sqrt{(1-\rho_0)^2 - m^2\,cos\theta}]$$



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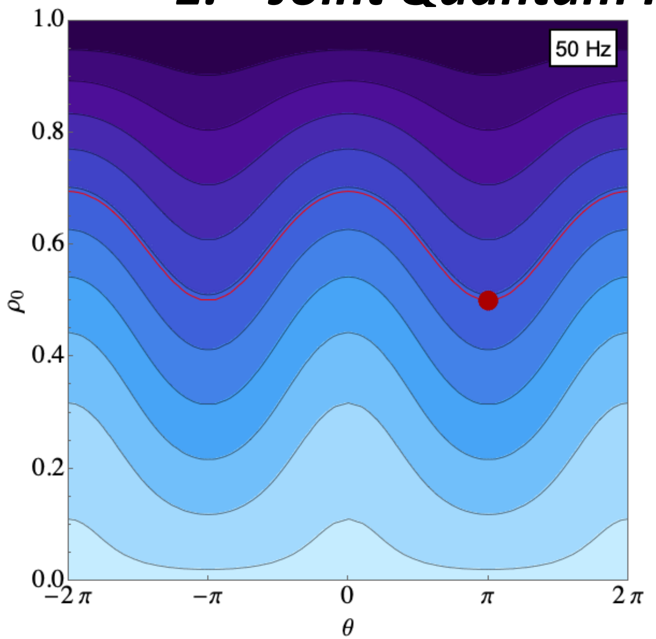

Thank you!