Phys. Rev. Lett. **107**, 145306 (2011)

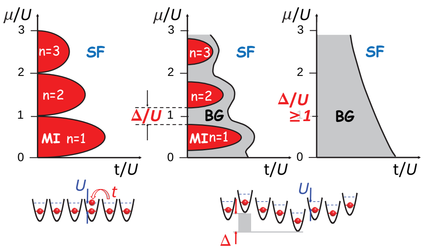
Glassy Behavior in a Binary Atomic Mixture

Bryce Gadway, Daniel Pertot, Jeremy Reeves, Matthias Vogt, and Dominik Schneble
Department of Physics and Astronomy, Stony Brook University, Stony Brook, New York 11794-3800, USA

Realizing Disorder with "Frozen" Impurities

Disordered Bose-Hubbard model

Giamarchi & Schultz (1988); Fisher et al (1989)

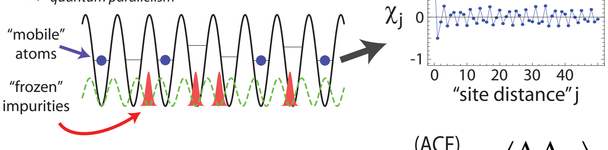


- Localized atomic impurities can act as point-like defects
  ⟶ weakly correlated disorder
  Gavish & Castin (2005) ; Paredes et al (2005) ; Horstmann et al (2010)
- Disordered "quantum emulsions" arise from homogenous mixtures + state-dependent potentials
  Roscilde & Cirac (2007) ; Buonsante et al (2008)

⟶ *out-ouf-equilibrium state with Bose-glass like characteristics*

Localized auxiliary spin state

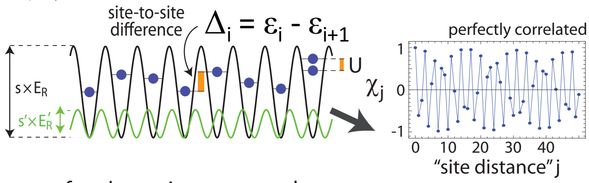
freeze out impurities from atomic spin mixture
⟶ *"quantum parallelism"*



(ACF) $\chi_j = \dfrac{\langle \Delta_i \Delta_{i+j} \rangle_i}{\langle \Delta_i \Delta_i \rangle_i}$

Weak incommensurate lattice

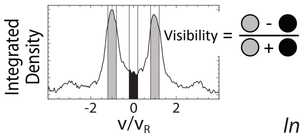
cf. expt. by Fallani et al (2007)

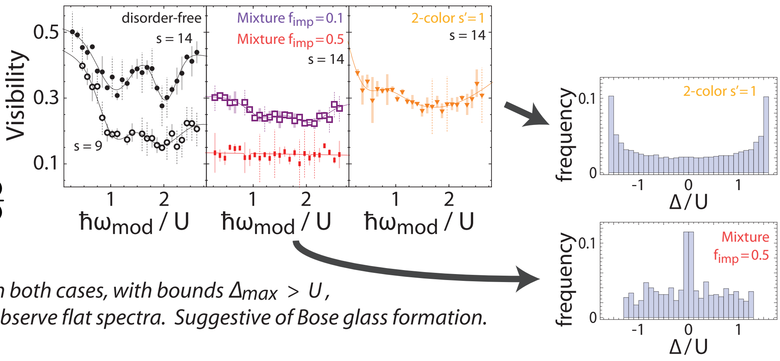


- Atoms of each species are strongly confined to one-dimensional tubes
  ($\omega_\perp \approx 2\pi \times 26$ kHz)

Excitation Spectra

- Amplitude-modulate z-lattice at frequency $\omega_{mod} / 2\pi$
  Stöferle et al (2004)
- Following thermalization, measure visibility in time-of-flight

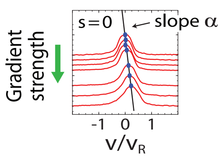




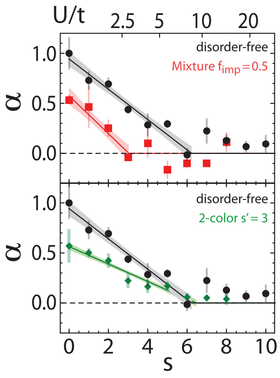
In both cases, with bounds $\Delta_{max} > U$, observe flat spectra. Suggestive of Bose glass formation.

1D Superfluid-to-Insulator Transition in the Presence of Disorder

Probing Transport

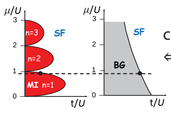


- Measure induced velocity in time-of-flight after pulsed-on B-field gradient and quick lattice ramp-off
  Haller et al (2010)

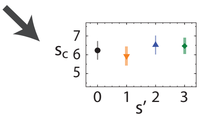


See large difference between correlated and uncorrelated disorder...

- Impurities ⟶ large shift of transition

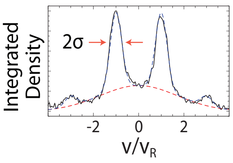


critical *t* goes up
⟺critical *s* goes down ✓

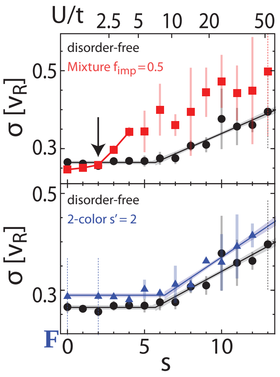


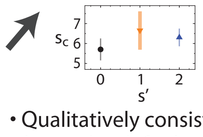
- For incommensurate lattice, no noticeable shift of transition point *(!)*

Probing Localization



- Time-of-flight width σ ⟶ in-situ correlation length ξ ($\sigma \propto \xi^{-1}$)
  Kollath et al (2004)





- Qualitatively consistent with transition at lower depth for less correlated disorder
  Roux et al (2008)
- Related to coherence-loss mechanism in Bose-Bose & Bose-Fermi mixture expts?
  Snoek et al (2011) ; Cramer (2011)
  Ospelkaus et al (2006) ; Günter et al (2006) ;
  Catani et al (2008) ; Best et al (2009)