Probing the Stability of Many-Body Localization

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Controlling quantum matter: From ultracold atoms to solids, Vilnius, 01.08.2018

Magnetic Polarons in Fermi Hubbard Systems

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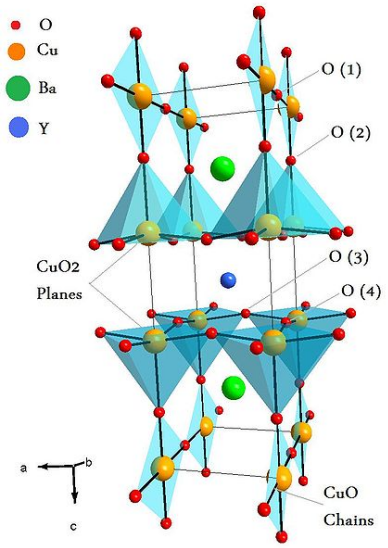
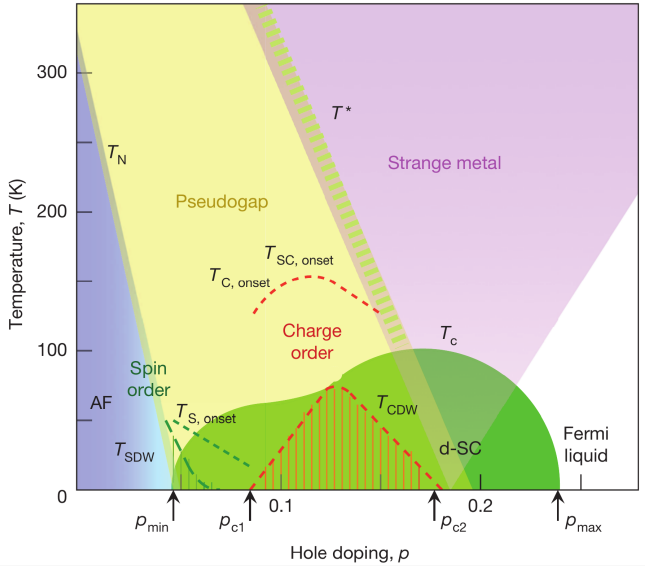
Controlling quantum matter: From ultracold atoms to solids, Vilnius, 01.08.2018

The physics of complex solid state materials



Cuprate unit cell ($YBa_2Cu_3O_7$)

Wikipedia



Keimer, Nature 2015

Prominent electronic toy model: **Hubbard model**

$$\hat{H} = -t \sum_{<i,j>,\sigma} \hat{c}^{\dagger}_{i,\sigma} \hat{c}_{j,\sigma} + U \sum_i \hat{n}_{i,\uparrow} \hat{n}_{i,\downarrow}$$

Review: Lee, RMP 2006

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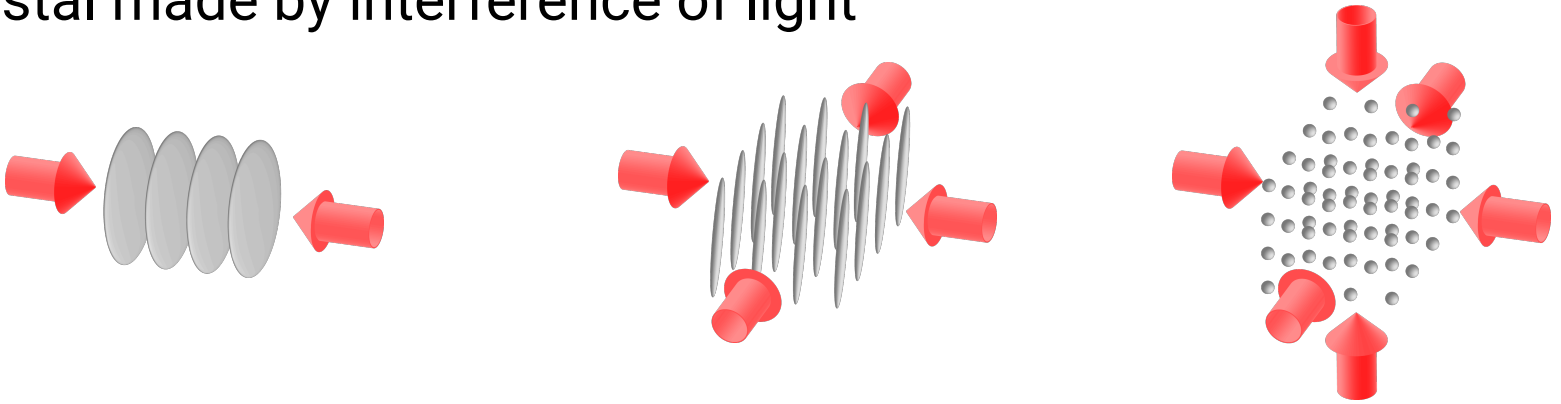
Hubbard models in optical lattices

A crystal made by interference of light



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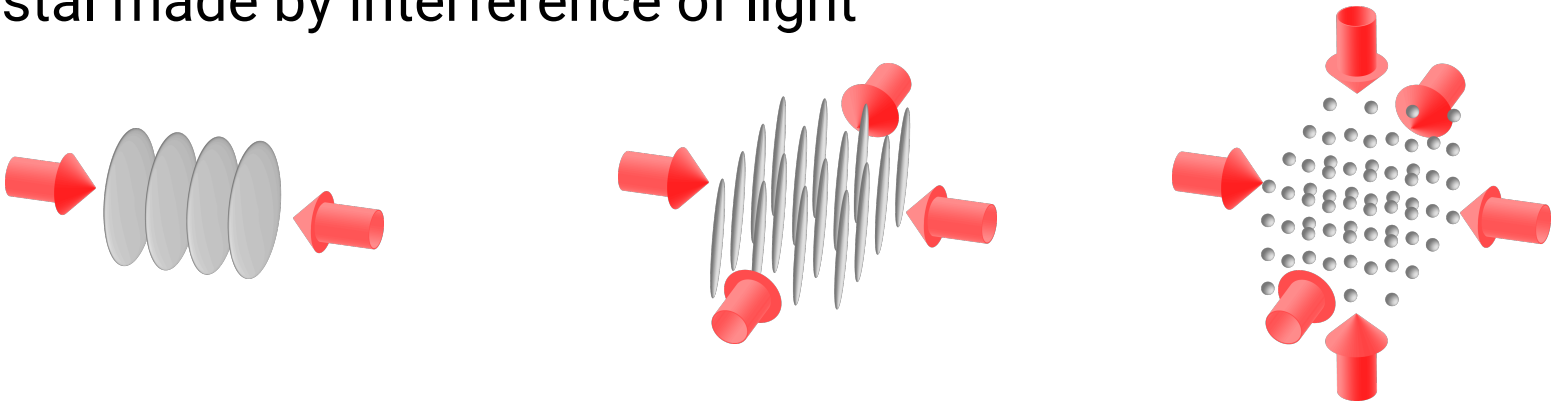
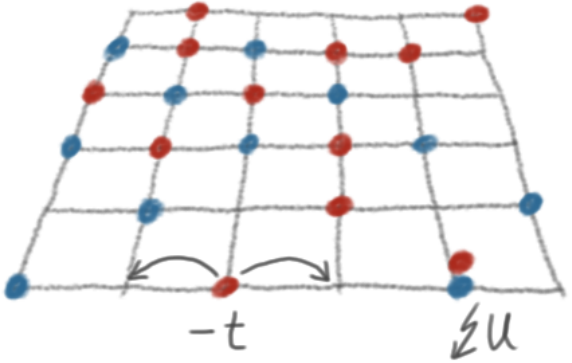


Mobile quantum particles in the lattice - Hubbard models

$$\hat{H} = -t \sum_{<i,j>,\sigma} \hat{c}^{\dagger}_{i,\sigma} \hat{c}_{j,\sigma} + U \sum_i \hat{n}_{i,\uparrow} \hat{n}_{i,\downarrow}$$

Emerging magnetic energy scale $J = \frac{4t^2}{U}$



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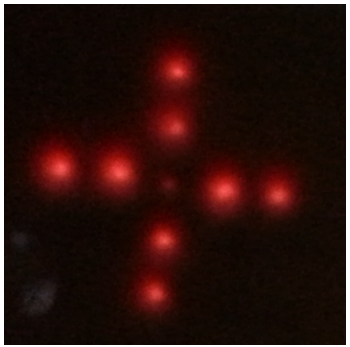
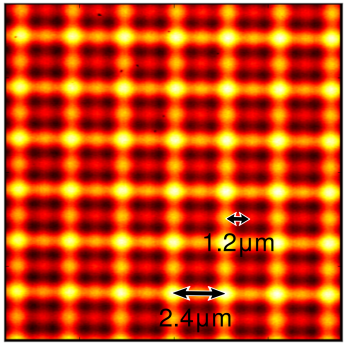
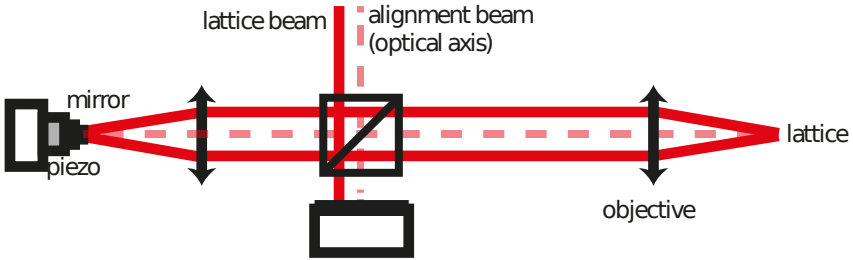
A specialized quantum gas microscope



Fourier plane



Atomic plane



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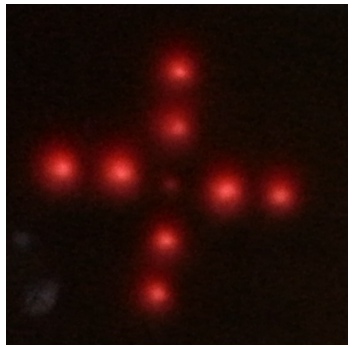

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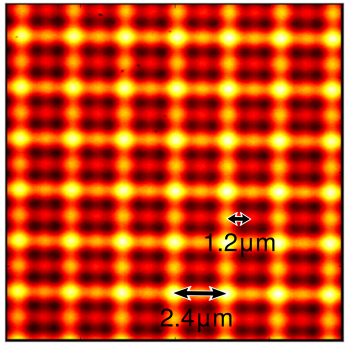

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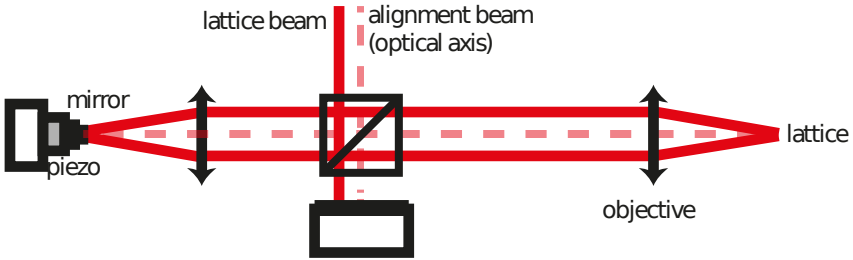
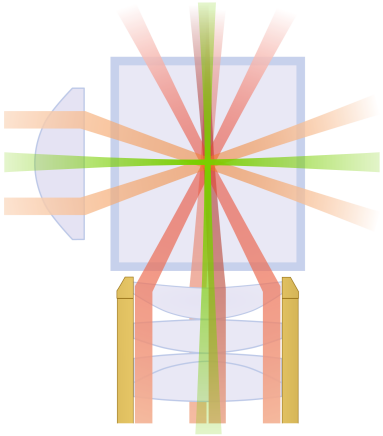
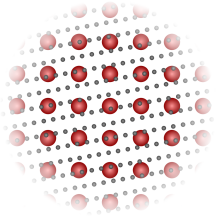
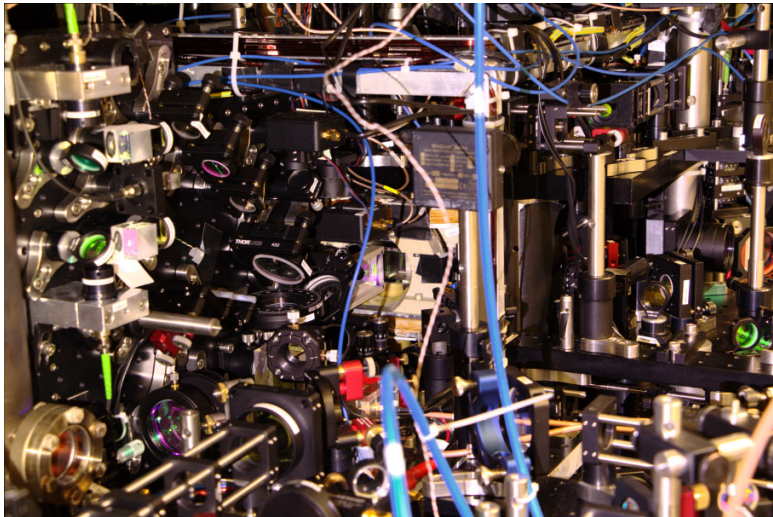




Independent optical lattices for imaging





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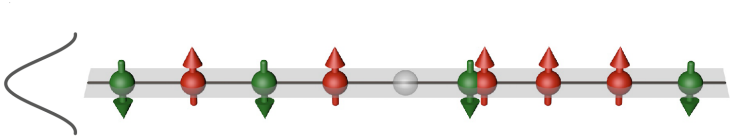
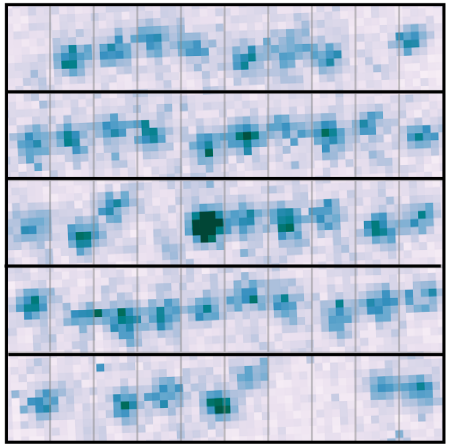
Imaging spins and "charges"





Boll, Science 2016

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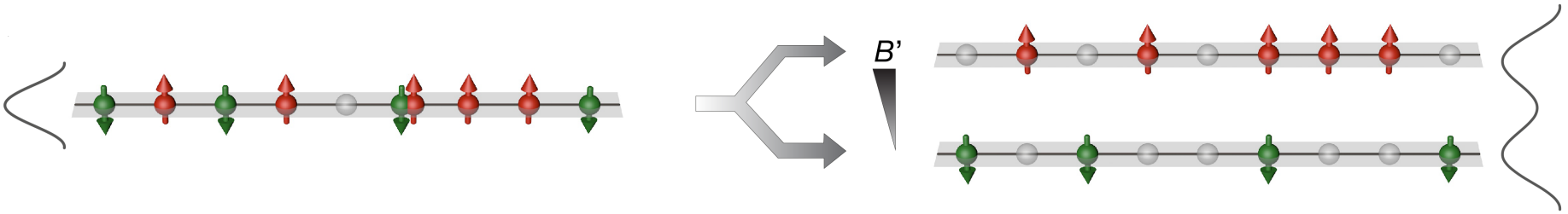

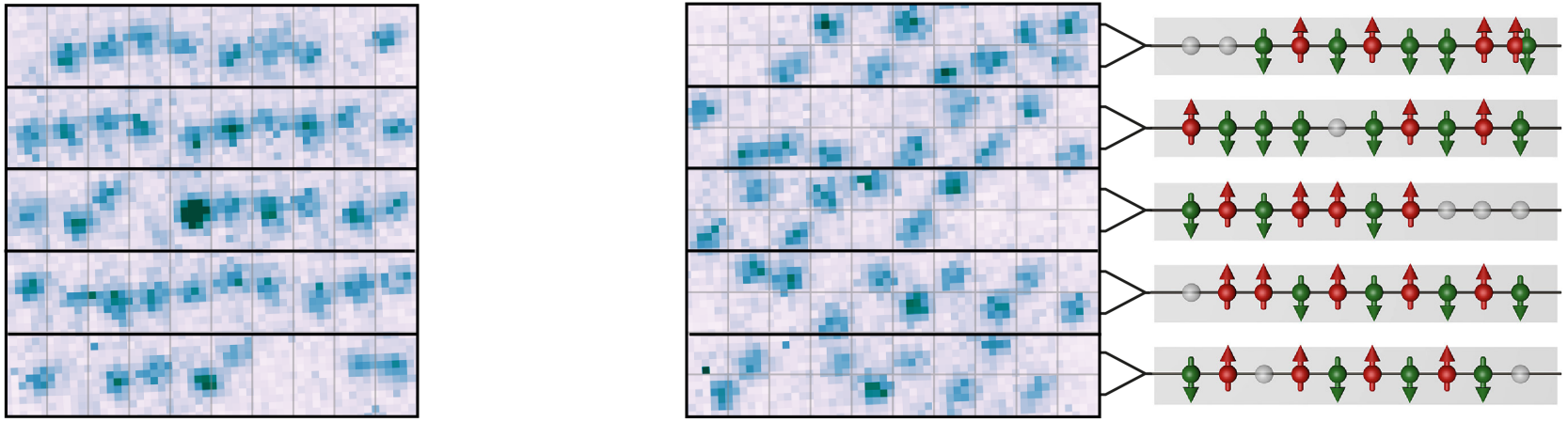

Full local information: Density and Spin

Access to spin-spin and spin-density correlations

Boll, Science 2016

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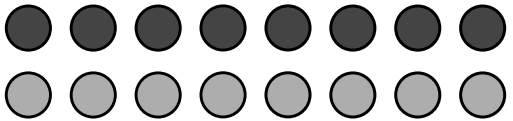
Doping the 1d Hubbard model

Charge sector: Delocalization

$$\hat{H} = -t \sum_{<i,j>,\sigma} \hat{c}^{\dagger}_{i,\sigma} \hat{c}_{j,\sigma} + U \sum_i \hat{n}_{i,\uparrow} \hat{n}_{i,\downarrow}$$



Spin sector: Antiferromagnetism

$$\hat{H}_{\mathrm{Heis}} = J \sum_i \hat{\mathbf{S}}_i \cdot \hat{\mathbf{S}}_{i+1}$$

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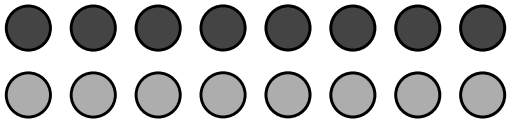

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What is the spin alignment around holes?

$|\Psi\rangle =$ 

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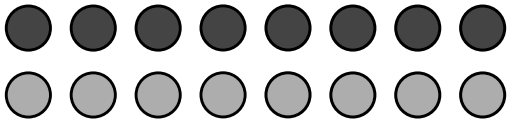

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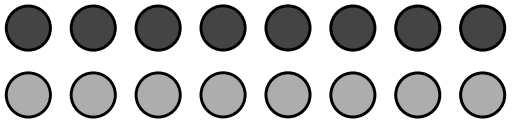

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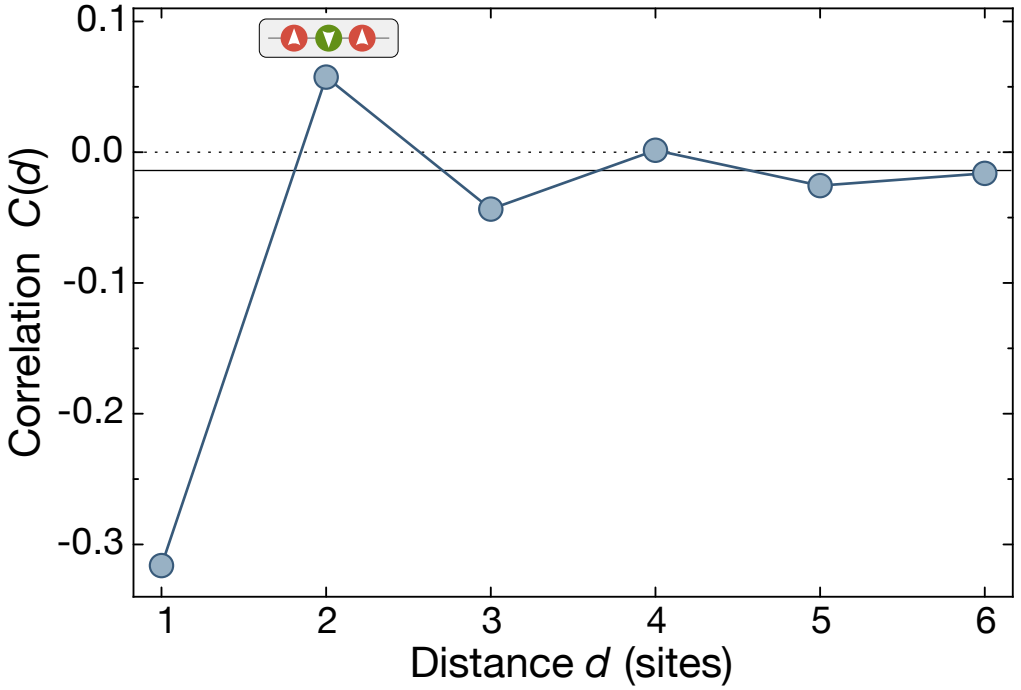
Spin alignment across holes

$$C_{SH,N_h}(d) = 4\,\langle \hat{S}_i^z \hat{S}_{i+d}^z \rangle_{\bigcirc_i \{\bullet\}_{N_h} \bigcirc_{i+d}}$$



Hilker, Science 2017

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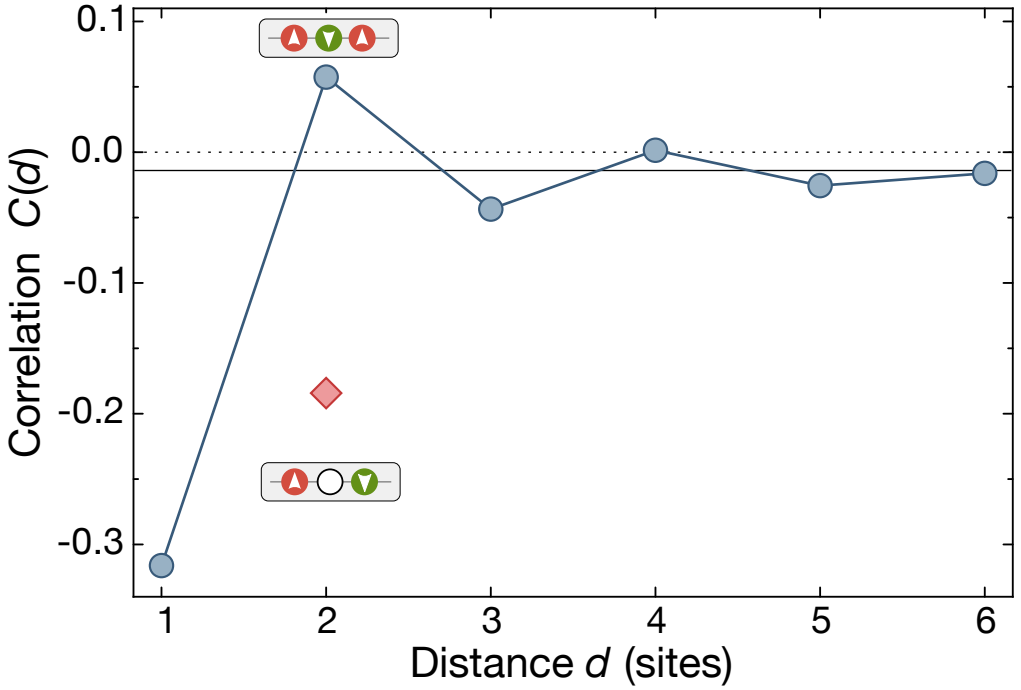

Hilker, Science 2017

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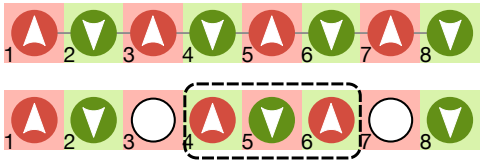
Hidden correlations

AFM parity flips suppress the standard 2-point correlator

$$C(d) = 4\left(\langle \hat{S}_i^z \hat{S}_{i+d}^z \rangle_{\bullet_i \bullet_{i+d}} - \langle \hat{S}_i^z \rangle_{\bullet_i} \langle \hat{S}_{i+d}^z \rangle_{\bullet_{i+d}}\right)$$



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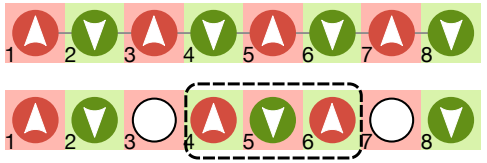
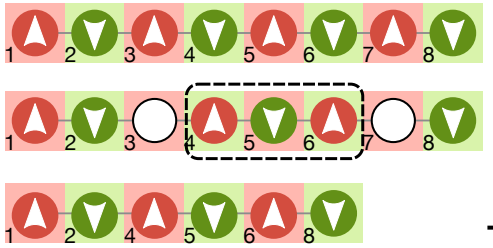


Reveal **hidden** spin correlations in "squeezed space"



→ discard sites with holes

Kruis, PRB 2004 | Kruis, EPL 2004

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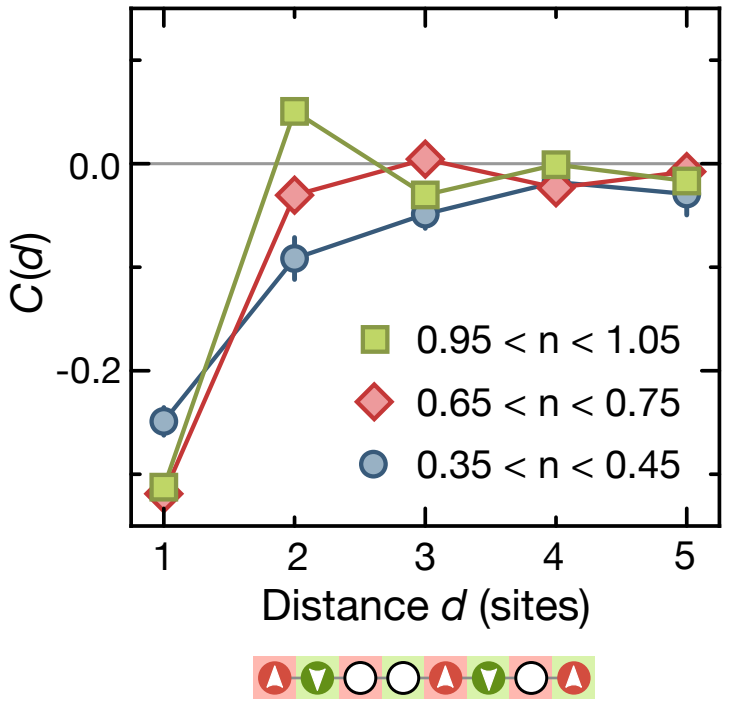
Correlations in squeezed space

Standard 2-point correlator



Hilker, Science 2017

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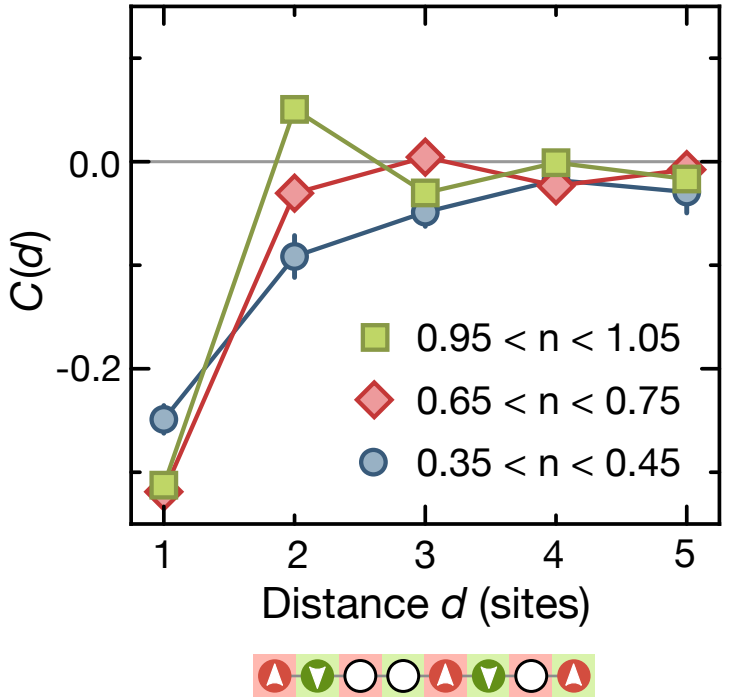
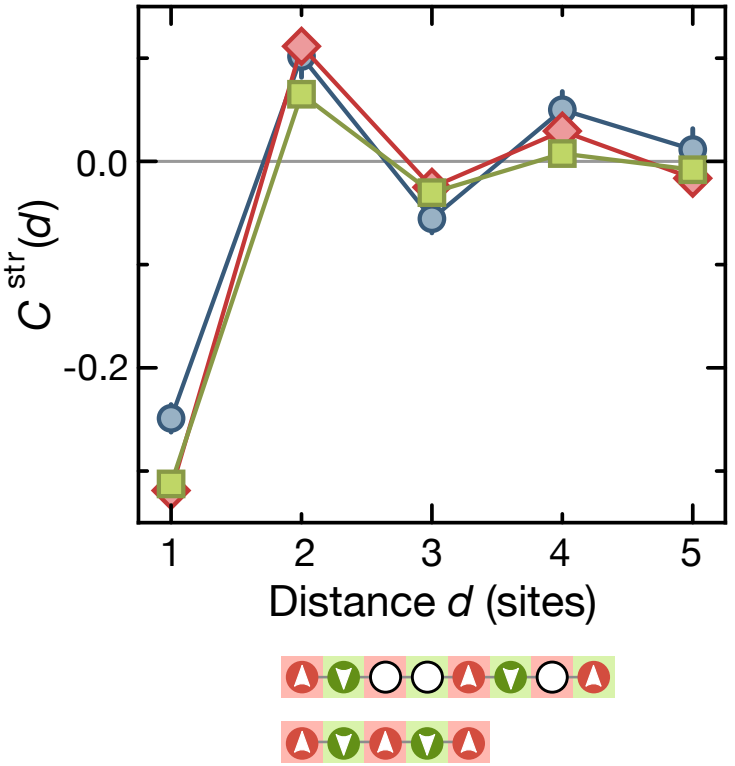
Standard 2-point correlator



Squeezed space 2-point correlator



→ **Spin-charge separation**

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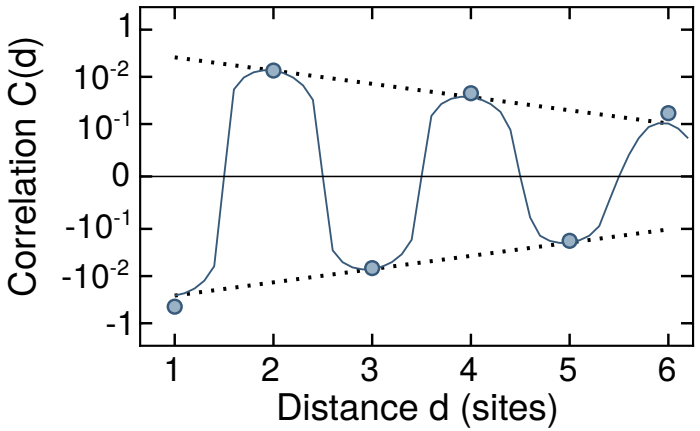
Incommensurate magnetism - charge

Holes / Doublons dilute (stretch) the spin correlations



Salomon, arXiv: 1803.08892

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Incommensurate magnetism - charge

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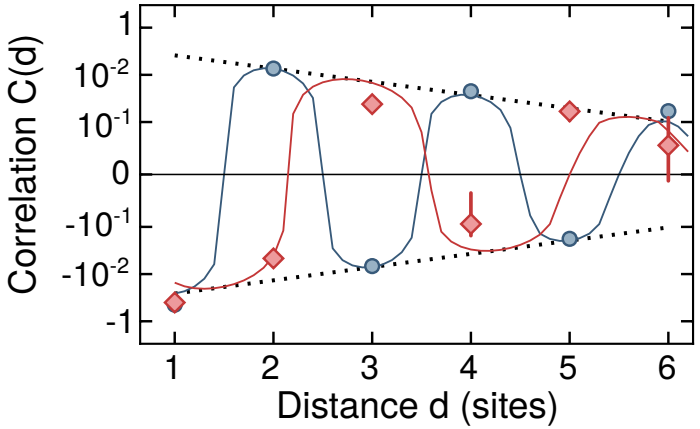

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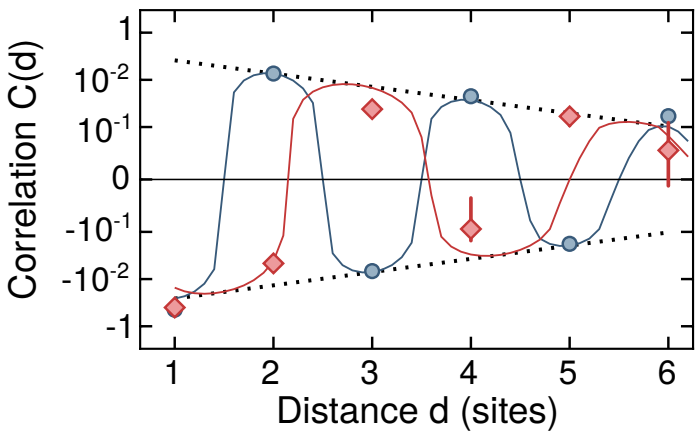
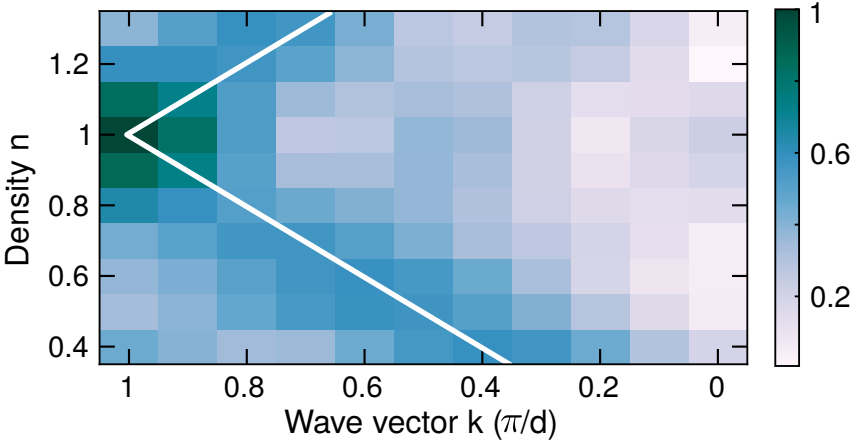




Linear density dependence of the wave vector
(as expected by Luttinger theory)

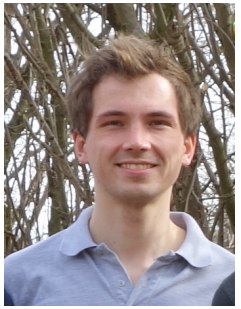
$$\langle \hat{S}_i^z \hat{S}_{i+d}^z \rangle \propto \cos(\pi(1-n_h)d)$$

Salomon, arXiv: 1803.08892

Thank you!

The Lithiums


Guillaume


Joannis


Timon

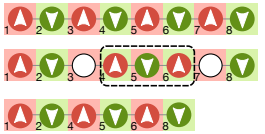

Jayadev

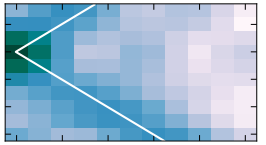

Mim


Immanuel

+ Eugene and Fabian @ Harvard

Summary


Hidden magnetism
spin-charge separation


Incommensurate
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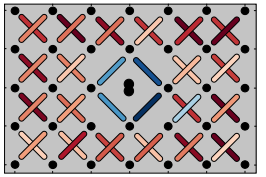
Magnetic polarons

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