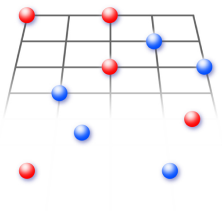
Discriminating antiferromagnetic signatures in ultracold fermions using tunable dimensionality and geometric frustration

Nils Blümer

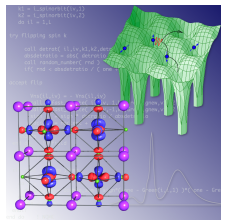
Institut für Physik, Johannes Gutenberg-Universität Mainz

[Phys. Rev. A **85**, 061602(R) (2012)]



TR 49: *Condensed matter systems with variable many-body interactions*
Frankfurt / Kaiserslautern / Mainz

FOR 1346
LDA+DMFT
Augsburg *et al.*



Acknowledgements

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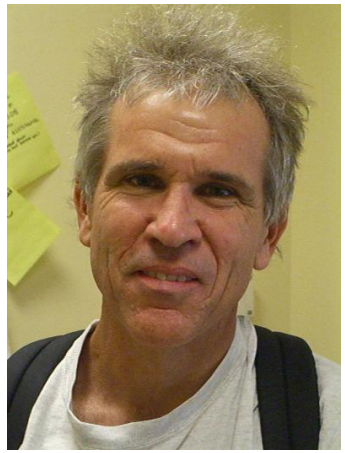
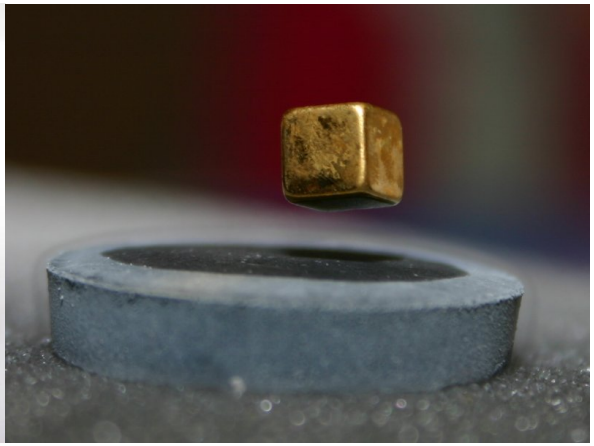
Rio de Janeiro

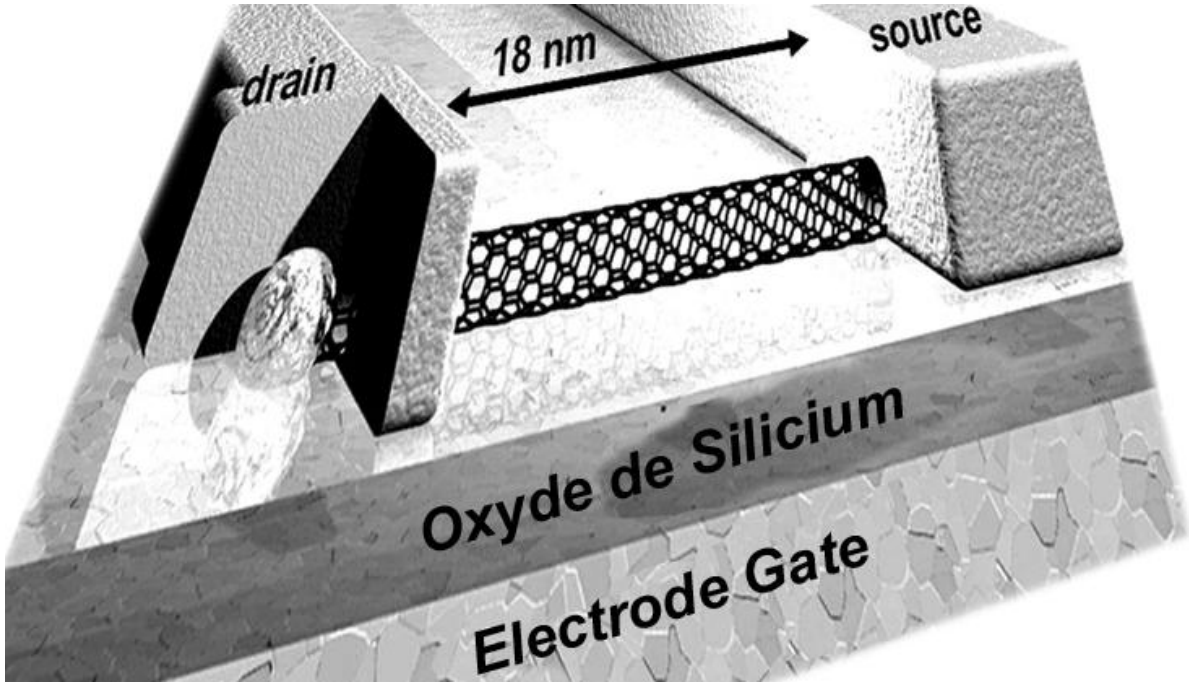


Richard Scalettar
UC Davis

Motivation: materials science, correlation phenomena

When and why are materials metallic, colored, magnetic, superconducting?





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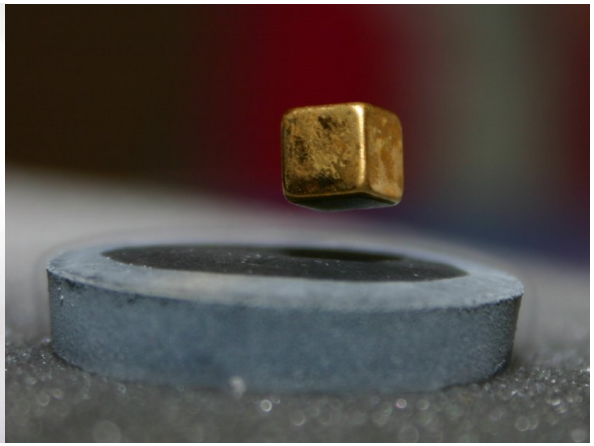
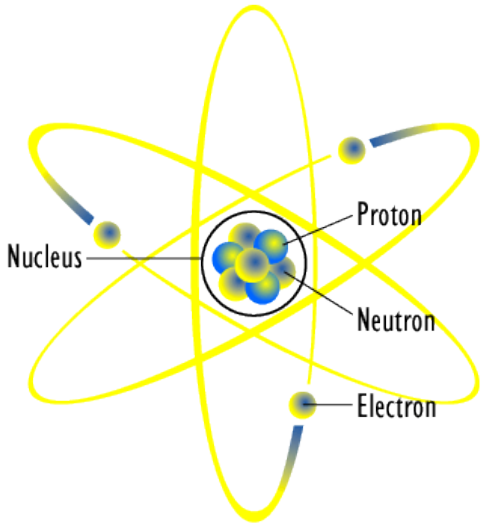
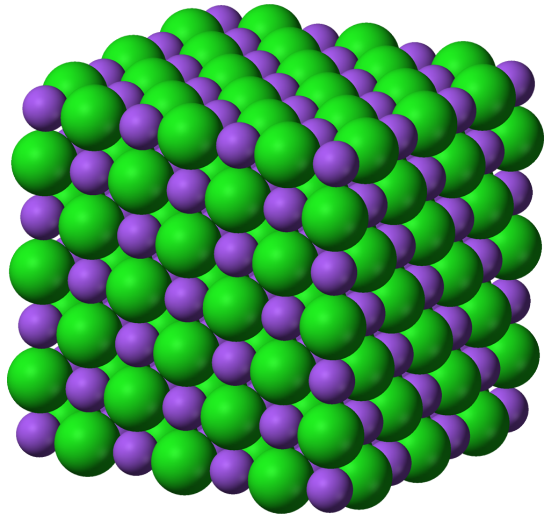


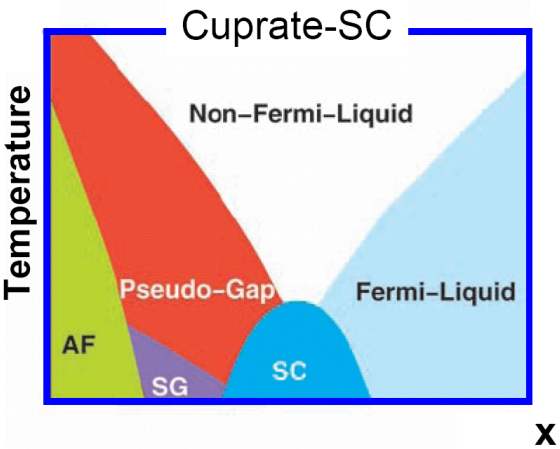
Structure: atoms (nuclei + electrons) in periodic arrangement



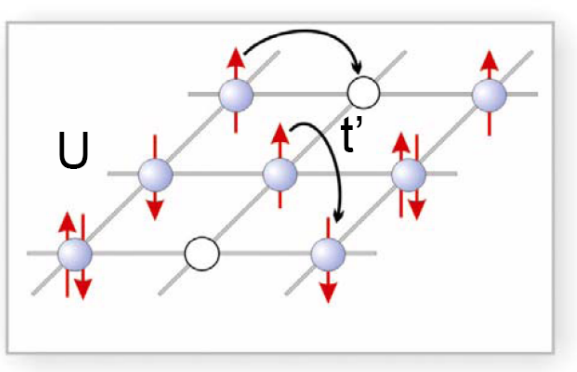


Motivation: Ultracold lattice fermions as quantum simulators?

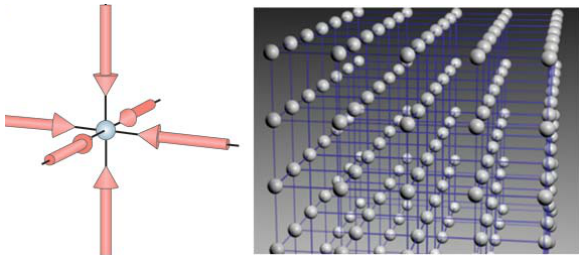
Correlated materials



Fermionic Hubbard model



Ultracold fermions on optical lattices



$\mathcal{O}(10^5)$ atoms

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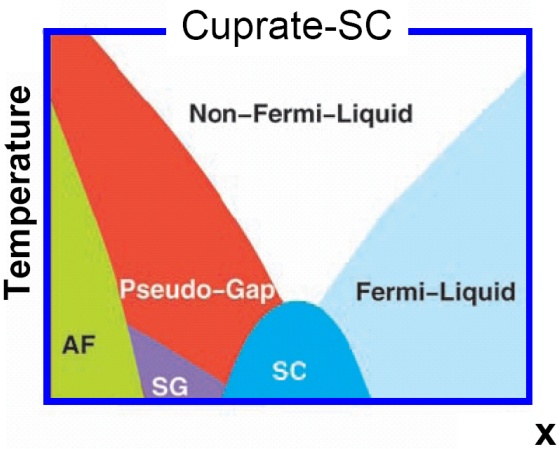

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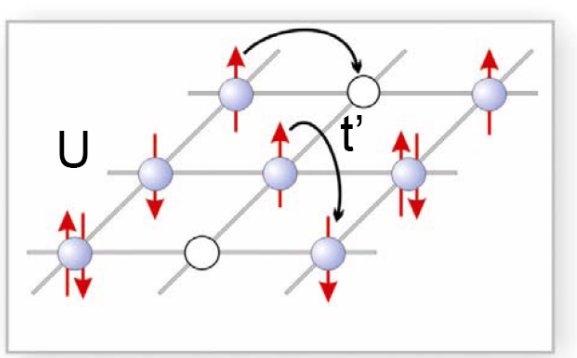

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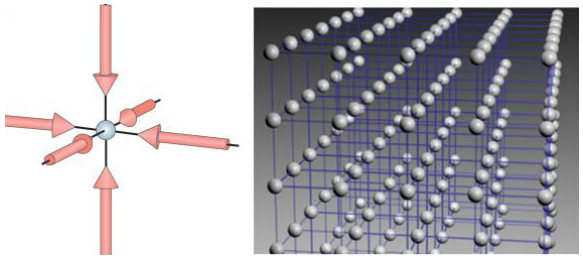
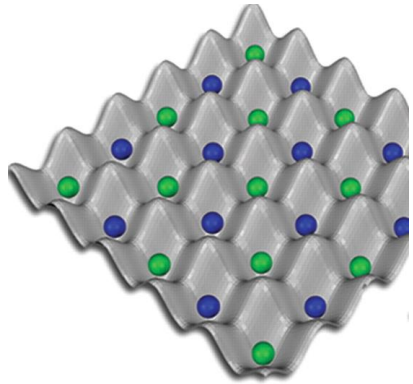


$\mathcal{O}(10^5)$ atoms

Recent breakthrough: paramagnetic Mott transition in fermionic 2-flavor mixtures

[Schneider et al., Science **322**, 1520 (2008), Jördens et al., Nature **455**, 204 (2008)]

Remaining challenge: antiferromagnetism (staggered order)



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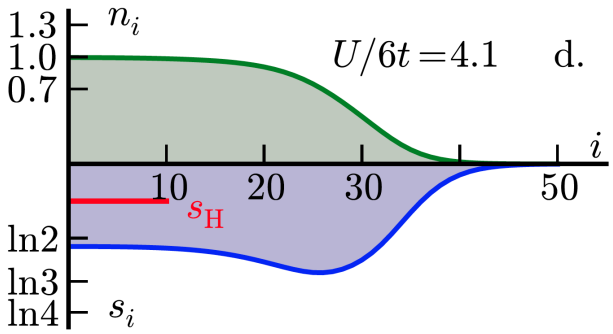

[Jördens et al., PRL **104**, 180401 (2010)]

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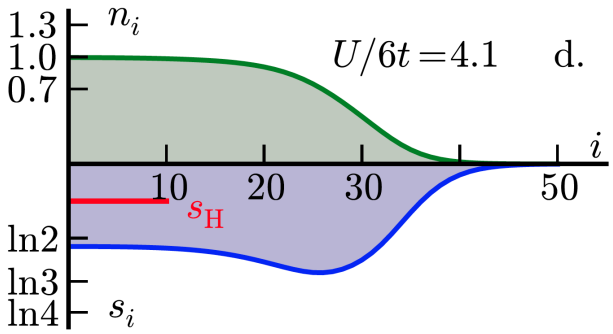
Mermin-Wagner: LRO $\leftrightarrow d = 3$



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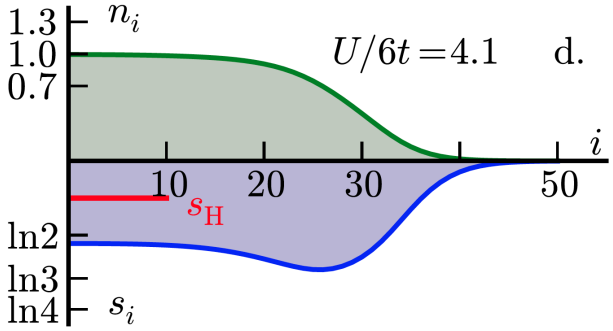

[Jördens et al., PRL **104**, 180401 (2010)]

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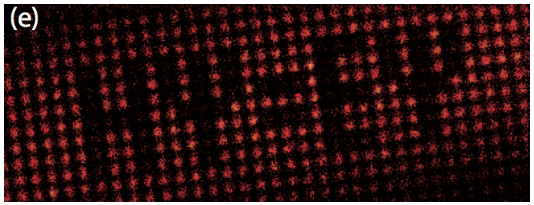
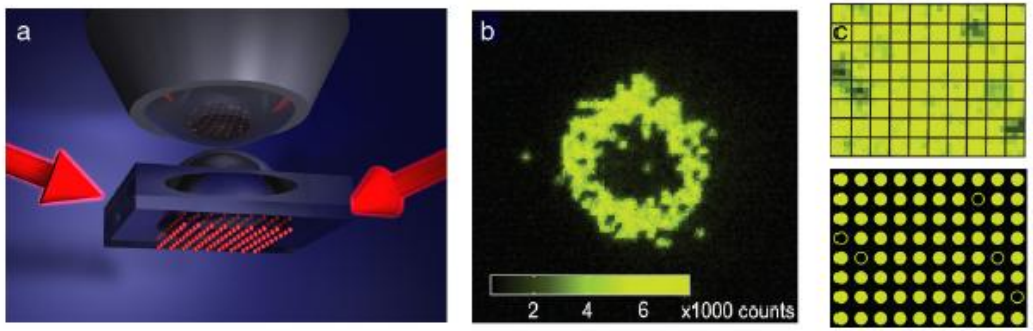
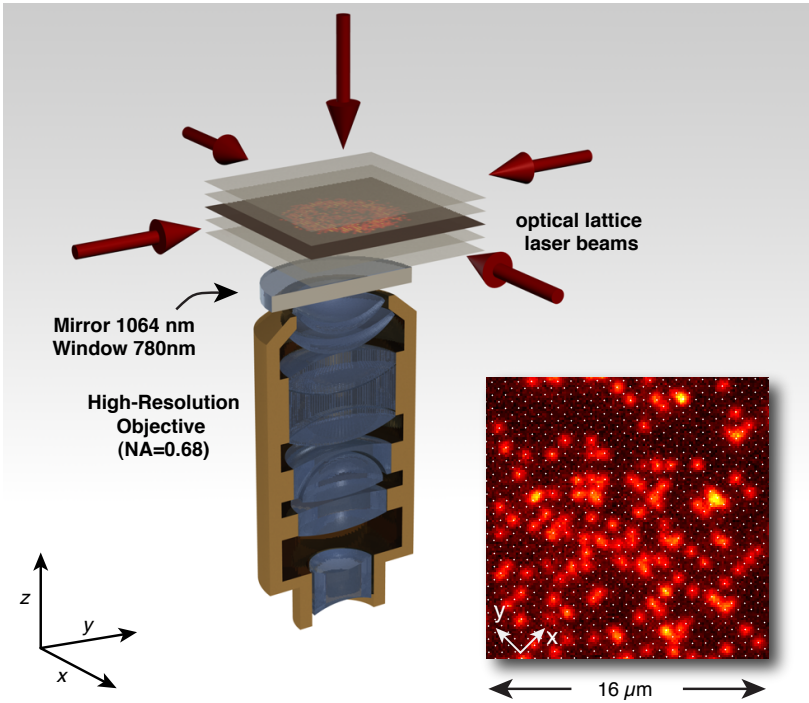
Experimental advantage of 2 dimensions: single-site resolution



[Würtz et al., PRL **103**, 080404 (2009)]

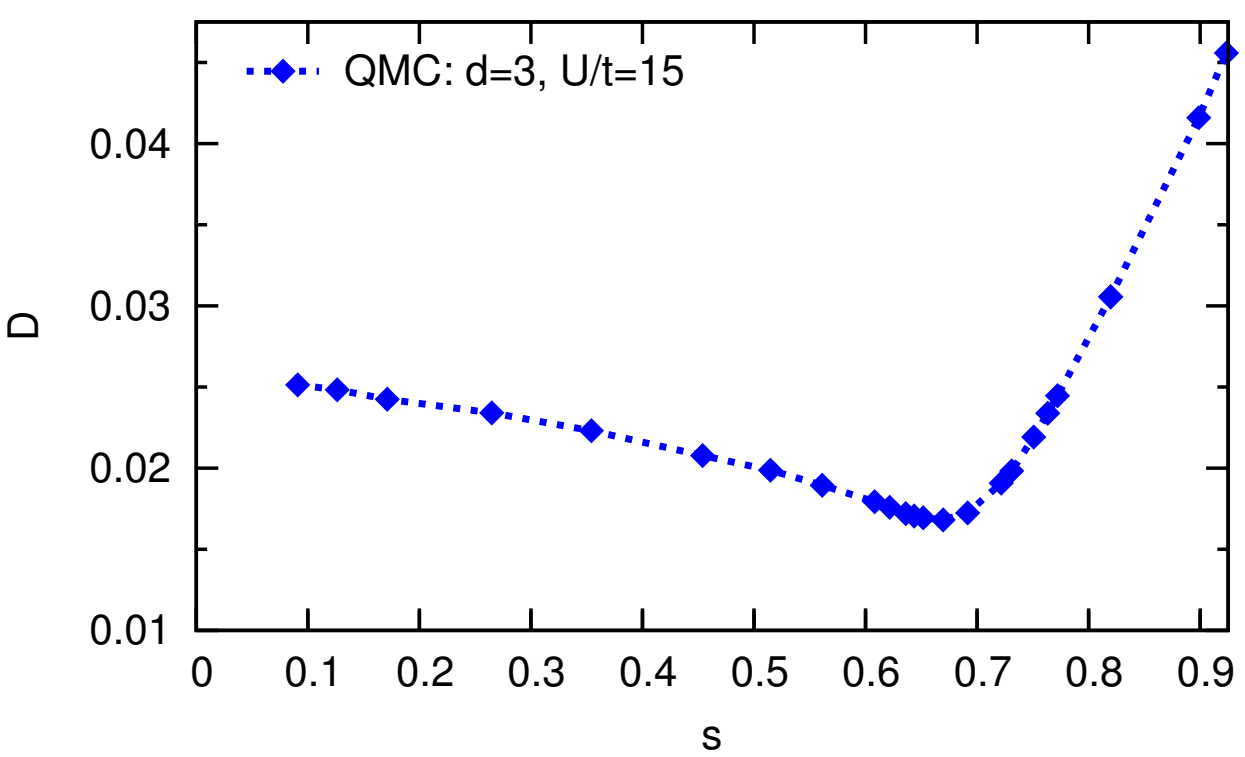


[Bakr et al., Science **329**, 547 (2010)]



[Sherson et al., Nature **467**, 68 (2010)]

Double occupancy as a universal measure of AF correlations + entropy



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AF enhances D at low-s

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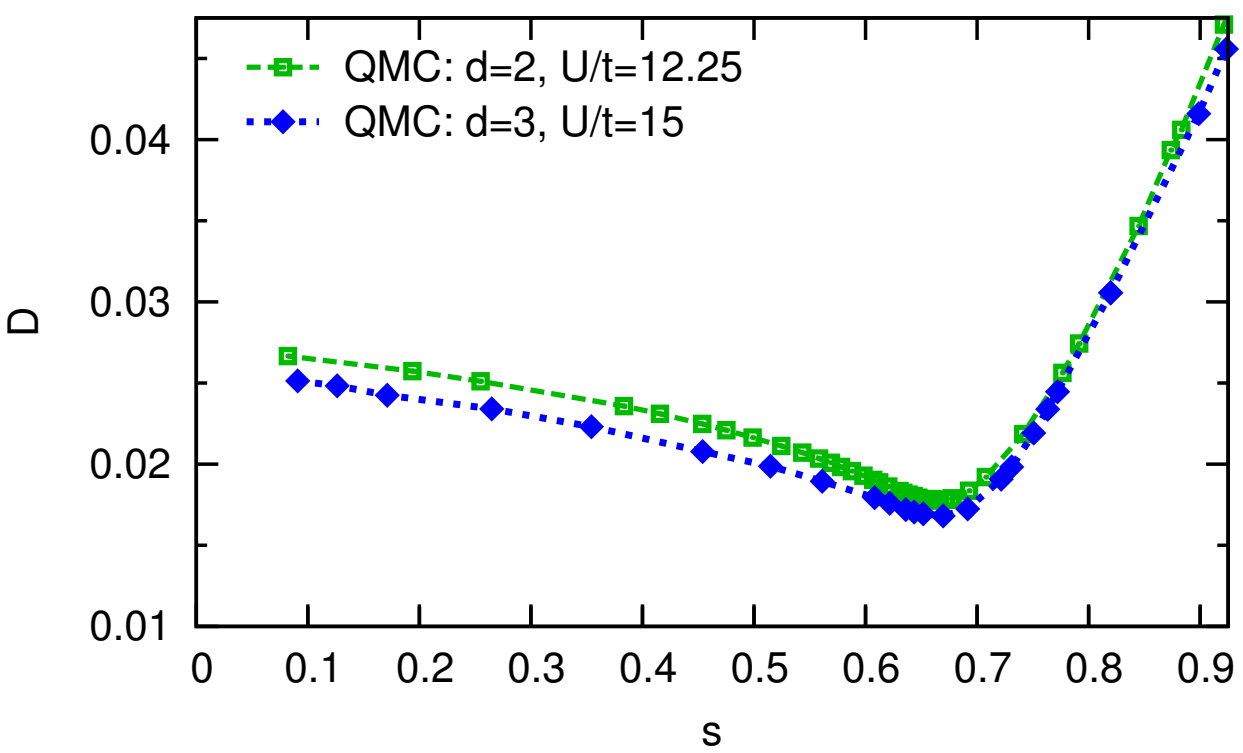

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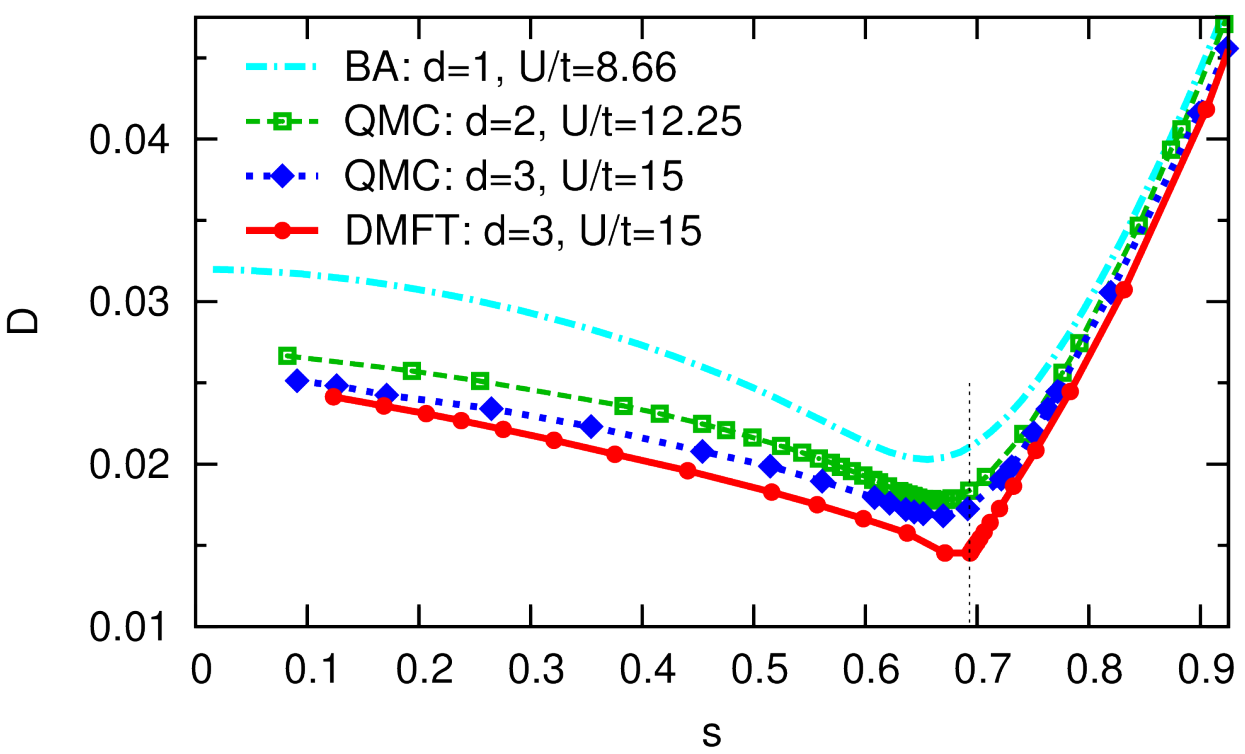

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Universal minimum at

$s \approx \ln 2$ for $1 \leq d \leq \infty$

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$\ln(2)/2 \lesssim s \lesssim \ln(2)$!

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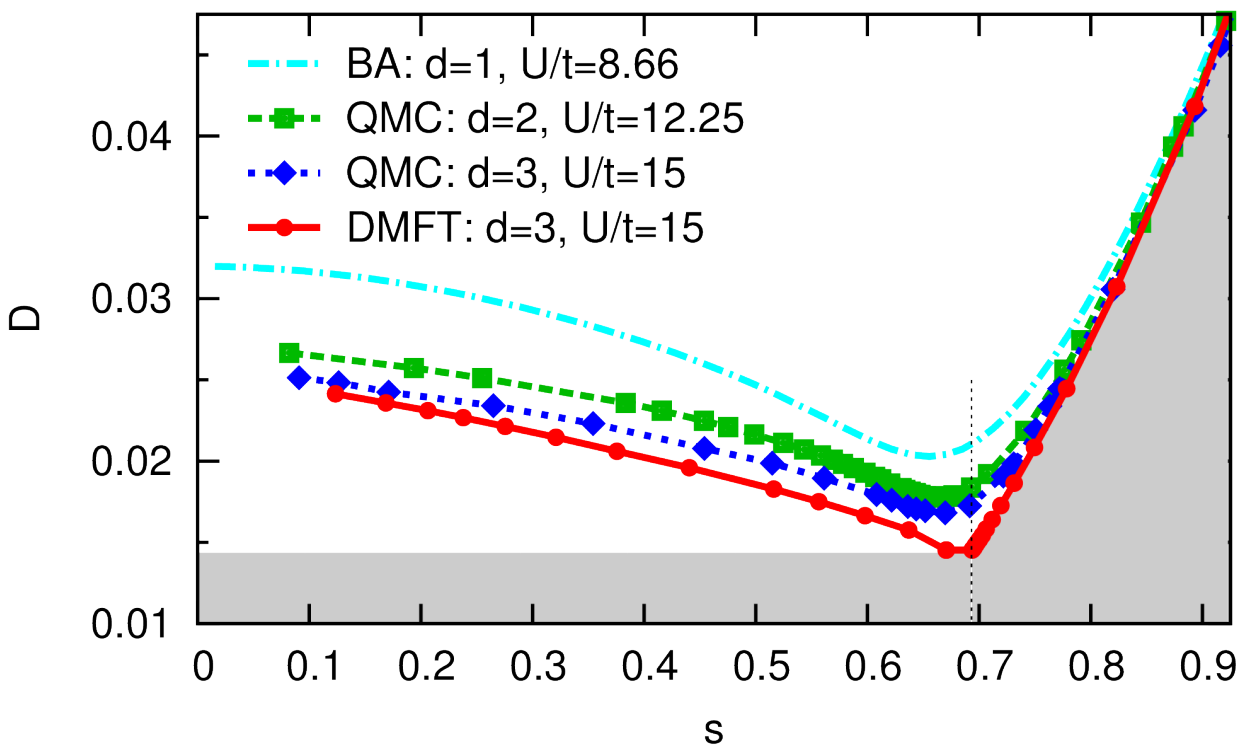

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AF enhancement of D is larger
in lower dimensions:

$$D_0 = (1 - \langle \boldsymbol{\sigma}_i \cdot \boldsymbol{\sigma}_j \rangle)\, Z \frac{t^2}{2U^2} + \mathcal{O}\left(t^4/U^4\right)$$

$$\langle \boldsymbol{\sigma}_i \cdot \boldsymbol{\sigma}_j \rangle_0 = \begin{cases} -1.00 & DMFT \\ -1.20 & (d=3) \\ -1.34 & (d=2) \\ -1.77 & (d=1) \end{cases}$$

Summary

NN AF correlations

LRO

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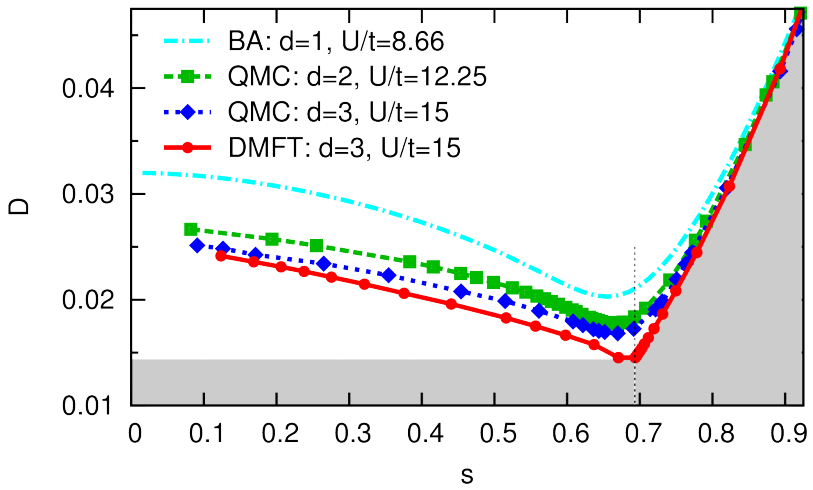
Double occupancy: nearly universal probe of AF correlations and entropy

Relevant entropy scale $s \lesssim \ln(2)$



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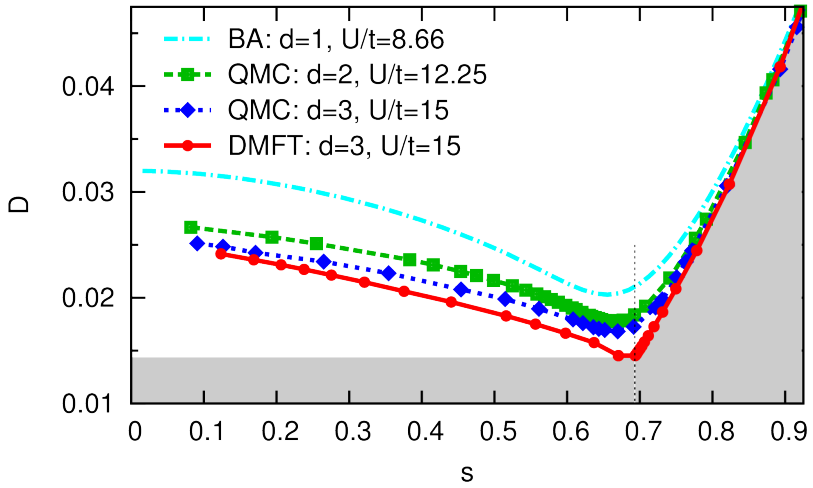

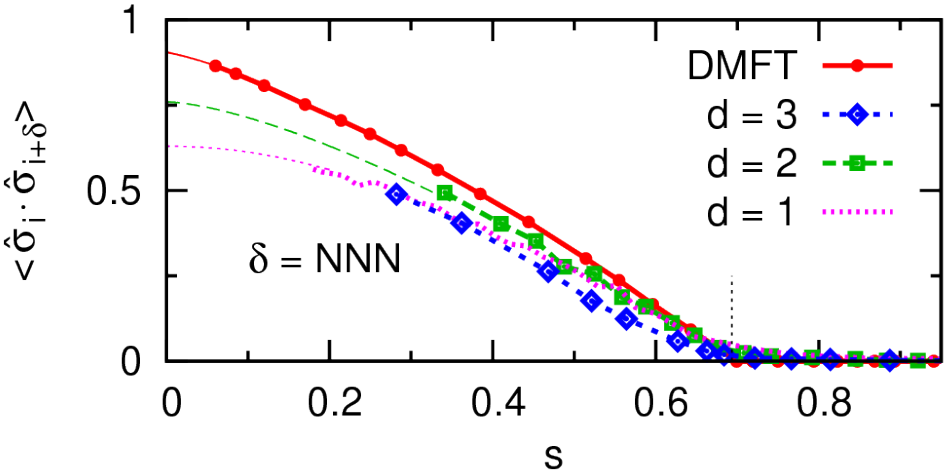

NNN spin correlations: universal signature of Heisenberg regime, low s