Ferromagnetism of a repulsive Fermi gas

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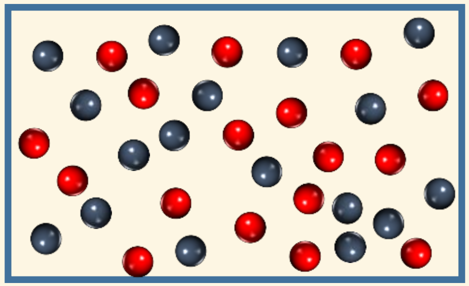
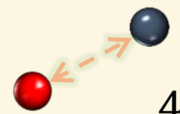
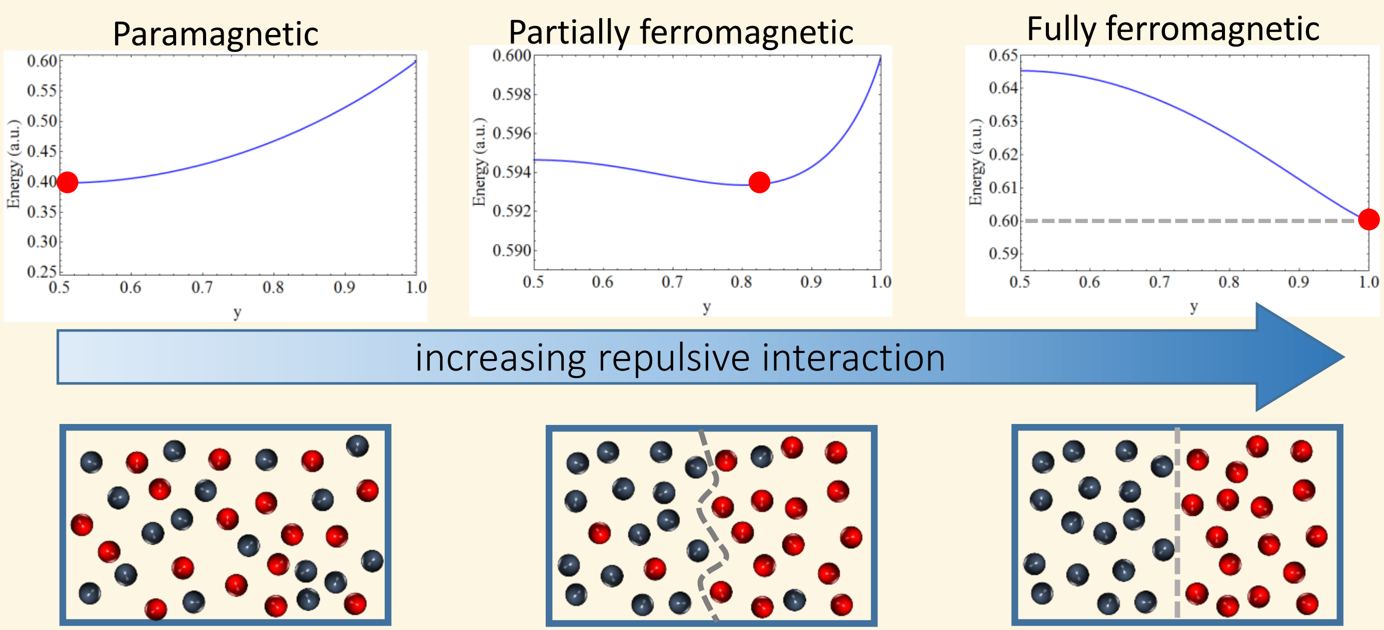
Repulsive Fermi gases





$$\sim \frac{4\pi\,\hbar^2 a}{m}\,\delta(\boldsymbol{r})$$

Stoner ('33): Perturbation theory & short-range repulsion: kinetic vs interaction energy

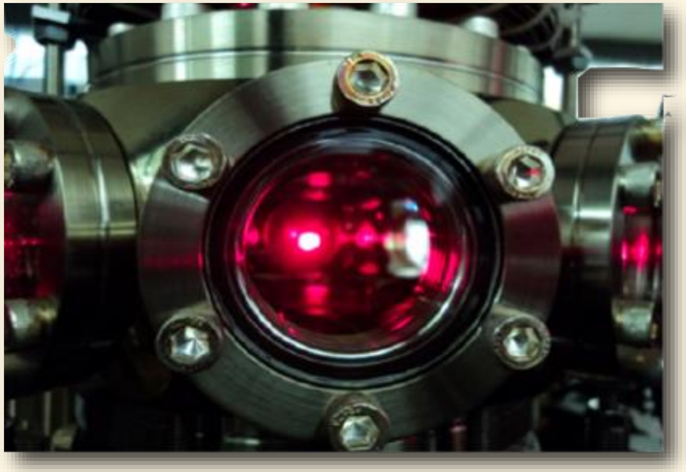


Why ultracold gases?

Fermi system with short repulsive interaction

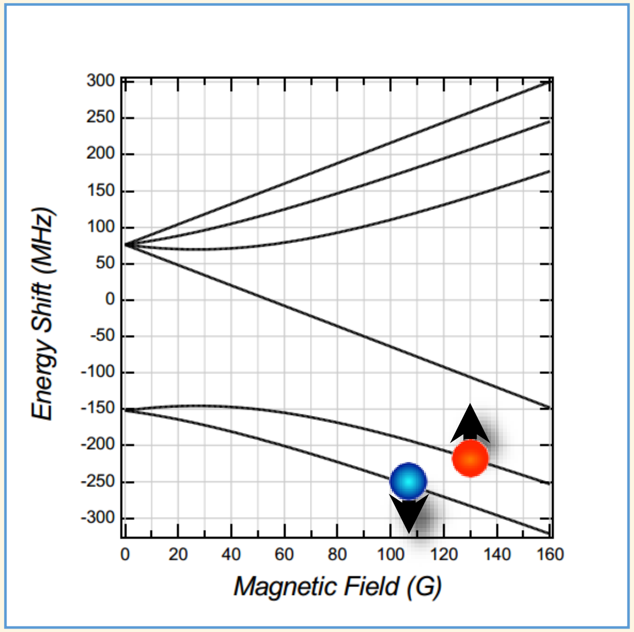
- No lattice
- No impurities (disorder)

Problem: Short-ranged repulsive interactions only if a bound state exists



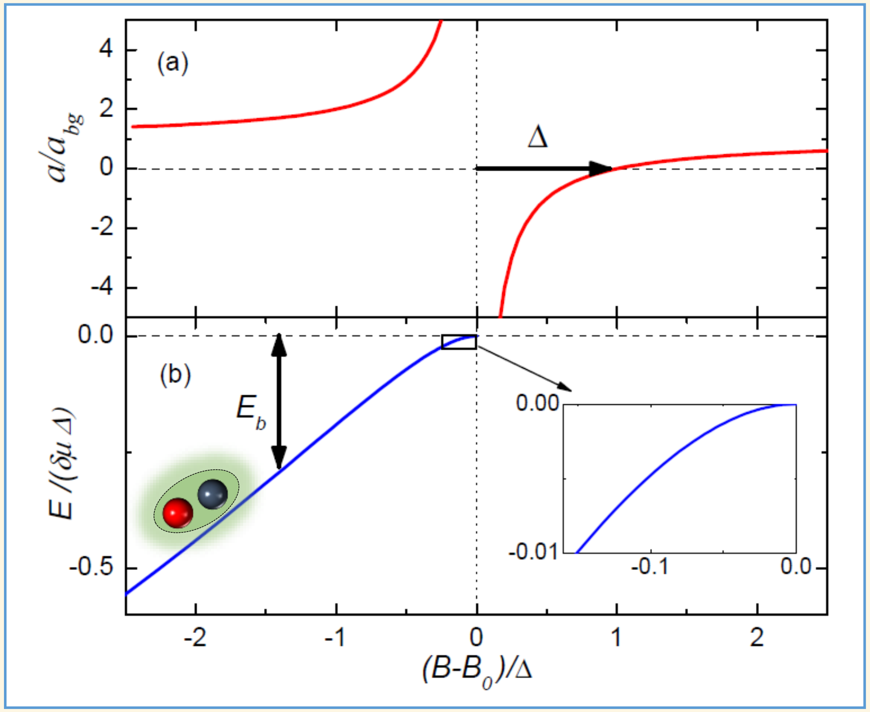
- Geometry
- Dimensionality (3D-2D-1D-0D)
- Temperature (T/TF)
- Population imbalance

Control of the interactions



Zeeman levels

C. Chin et al., Rev. Mod. Phys. **82**, 1225 (2010)



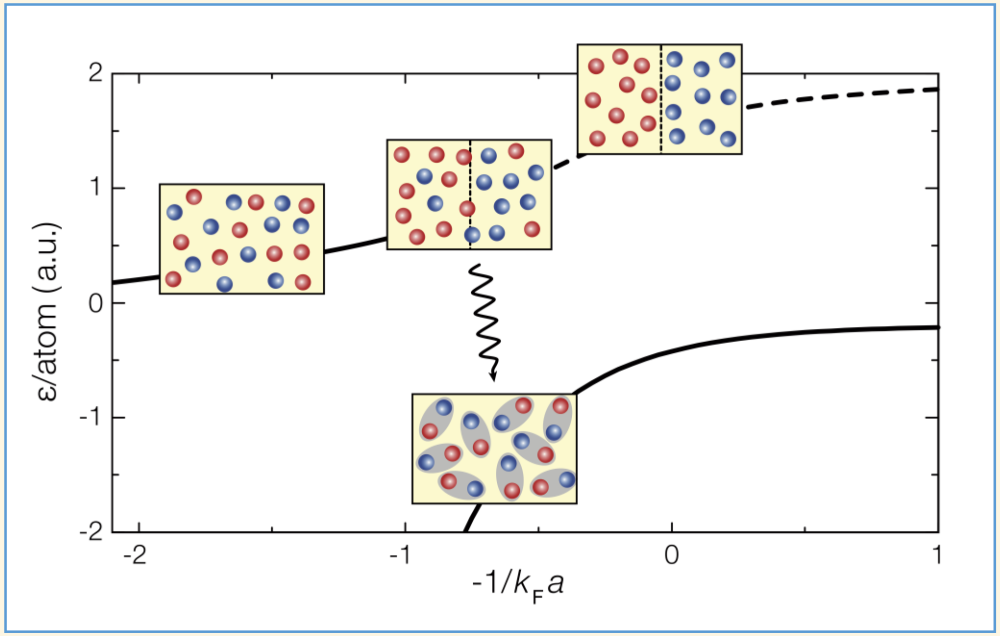
Fano-Feshbach resonance

Experimental tuning of the interactions

N(●) and N(●) fixed separately (no spin-exchange)

Spontaneaous magnetization → domains of unequal ● & ● densities

Short-ranged repulsive interactions only if a bound state exists



Repulsive Fermi gas intrinsically metastable (upper branch)

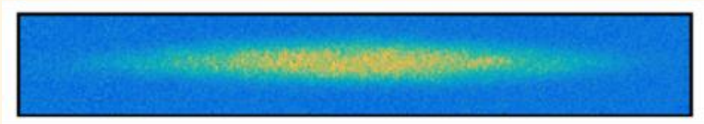
FM instability always competing with pairing

NJP **13**, 055003 (2011); PRA **80**, 051605(R) (2009); Ann. Phys. **326**, 2544 (2011); PRL **106**, 050402 (2011)

Our approach

1. Create a 1-2 Li mixture @300 G ($a_{12} \sim -300 a_0$) in a crossed trap

$\nu_{x,y} \sim 285\ Hz$
$\nu_z \sim 22\ Hz$

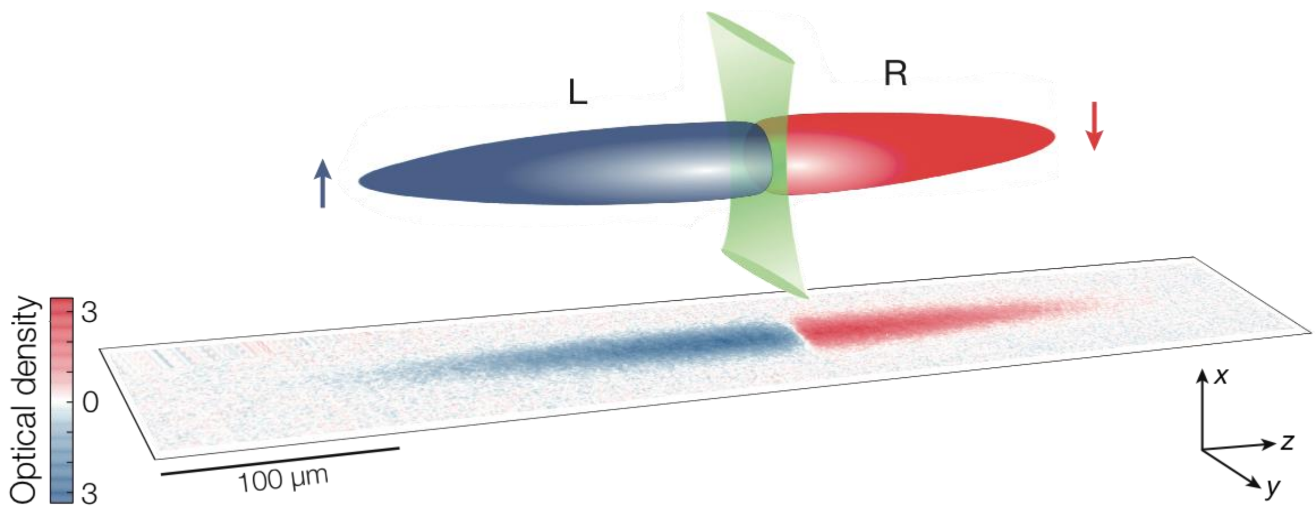


$N_{\uparrow,\downarrow} \sim 4-8\ 10^4$
$E_F \sim 7-11\ kHz$

$\boxed{\frac{T}{T_F} \sim 0.05-0.7}$

2. Adiabatically separate the two spin clouds @ 0.5G ($\mu_1 \sim -\mu_2$) via magnetic gradient

3. Rise up thin optical barrier, and ramp up the Feshbach field to B_f

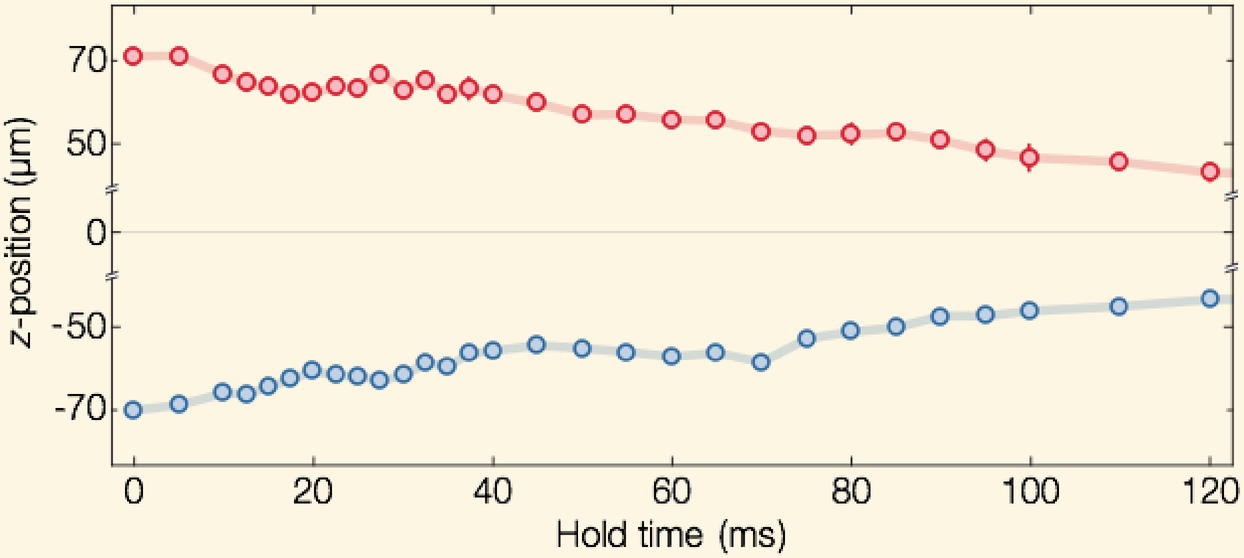


Sudden release of the barrier

Spin-dipole frequency univocally linked to spin susceptibility:

$$\omega_{SD}^2 = \frac{N_\uparrow + N_\downarrow}{m \int d\mathbf{r} z^2 \chi(n)}$$

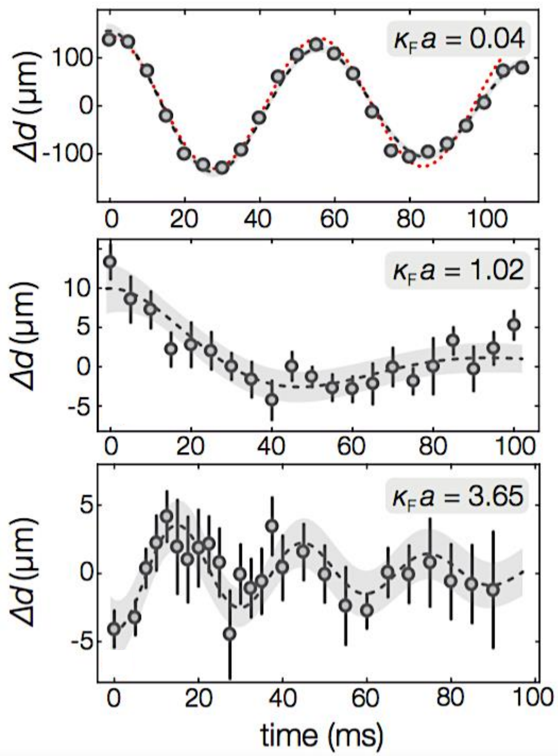
Softening of ν_{SD} unveils FM instability!

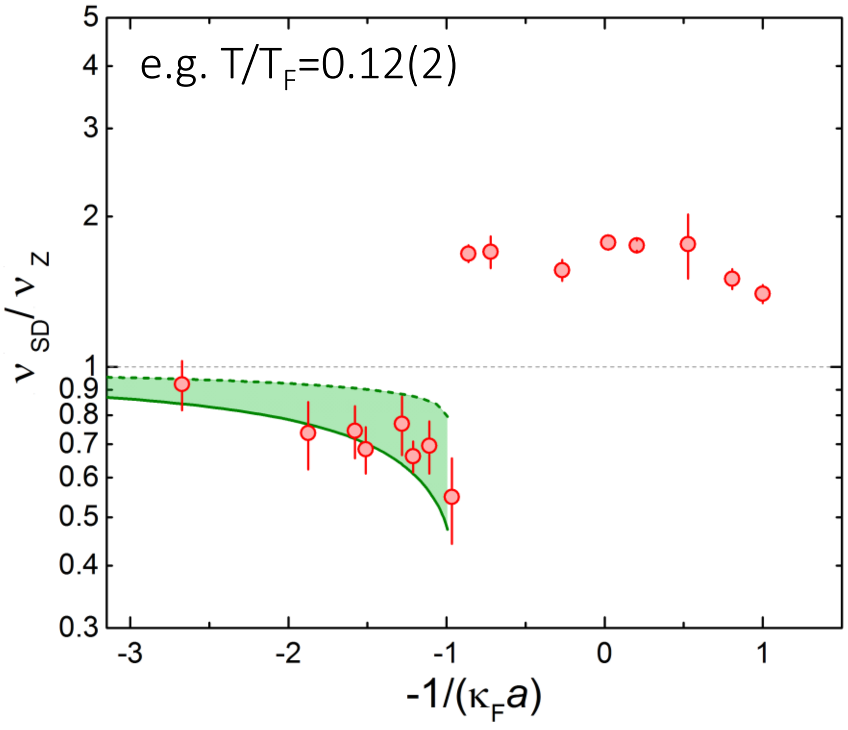


Small amplitude modulation on top of a slow (exponential) drift

Sudden release of the barrier

After removal of the drift via exp. fit… isolate out-of-phase motion $\Delta d(t)$





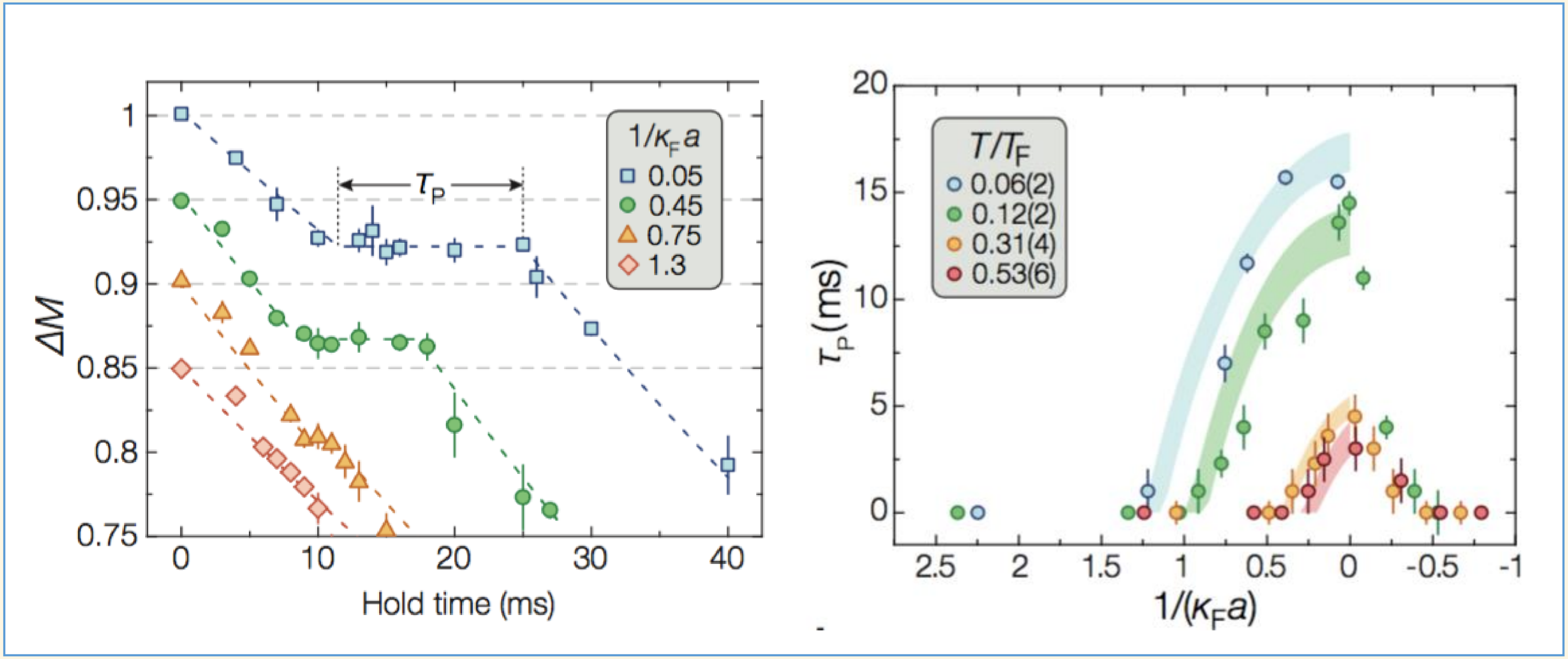
Theory by A. Recati for: 100% overlap

25% overlap

Adiabatic release of the barrier

Monitor magnetization dynamics after slow release at varying repulsion:

$$\Delta M = \frac{M_\uparrow - M_\downarrow}{2}$$

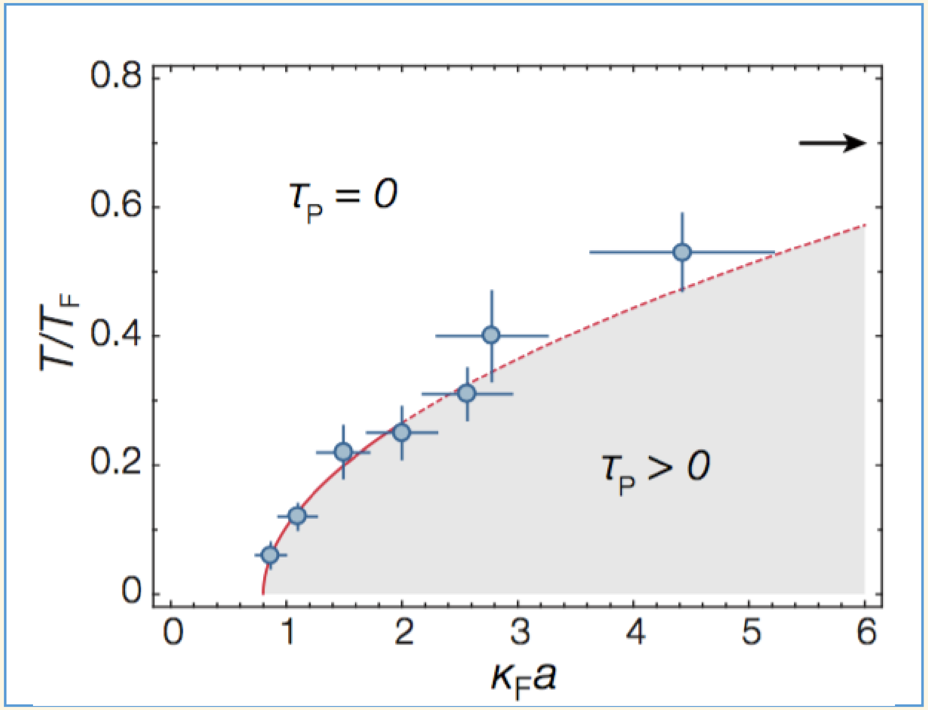


- At short evolution time, for strong repulsion, complete halt of spin dynamics!
- τ_P longer for large $\kappa_F a$ & low T. Duration explainable by repulsive polaron properties

Adiabatic release of the barrier

Close interconnection between jump of ν_{SD} in #1 and τ_P>0 in #2 !!

Use τ_p>0 to draw boundary for existence of a (meta)stable FM state



Conclusion and outlooks

Indication of a ferromagnetic instability (at least in a metastable sense) in a repulsive Fermi Gas

Softening of the spin dipole frequency

Freezing of the spin dynamics (short time)

G. Valtolina *et al*, arXiv:1605.07850

Outlooks:

- Study of repulsive and attractive polarons at broad Feshbach resonance (in progress).
- Implemenation of disorder in the system.
- Quasi-2D regime.

Thank you

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