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Diagnosing Strong Interactions via Signatures of Non-Markovian Dynamical Feedback on an Impurity Spin

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Background

We investigate the free induction decay of an impurity spin, embedded within a strongly correlated material, as the central process of a nuclear magnetic resonance.

Korringa law: relaxation rate of a nuclear spin embedded within a Fermi-gas is proportional to the temperature [1-2].

$$\frac{1}{T_1} \sim T$$

Based on **Markovian approximation**: The bath has no memory of prior interaction with impurity spin.

Power-law modification of Korringa relation is known for **strong interactions** within bath.

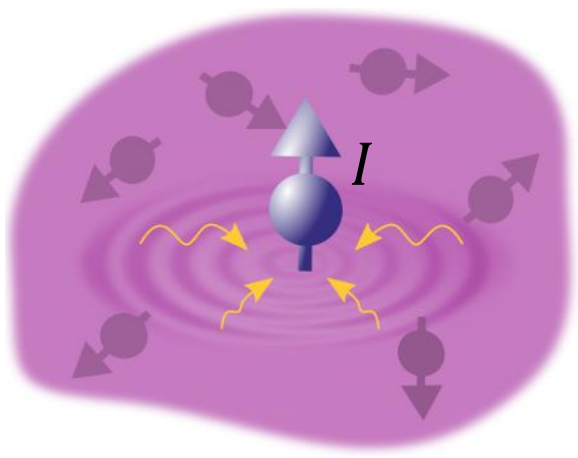
This **neglects temporal correlations** in the **initial joint-coherent dynamics**, which lead to an appreciable **slip in relaxation amplitude** at short times [3].

Is there a dynamical signature of strong interactions in the short term? What is the fate of the initial slip in amplitude?

Methodology

Impurity spin embedded within a bath

$$H = H_0 + H_I + H_{int}$$
$$H_{int} = A I \cdot S_0$$

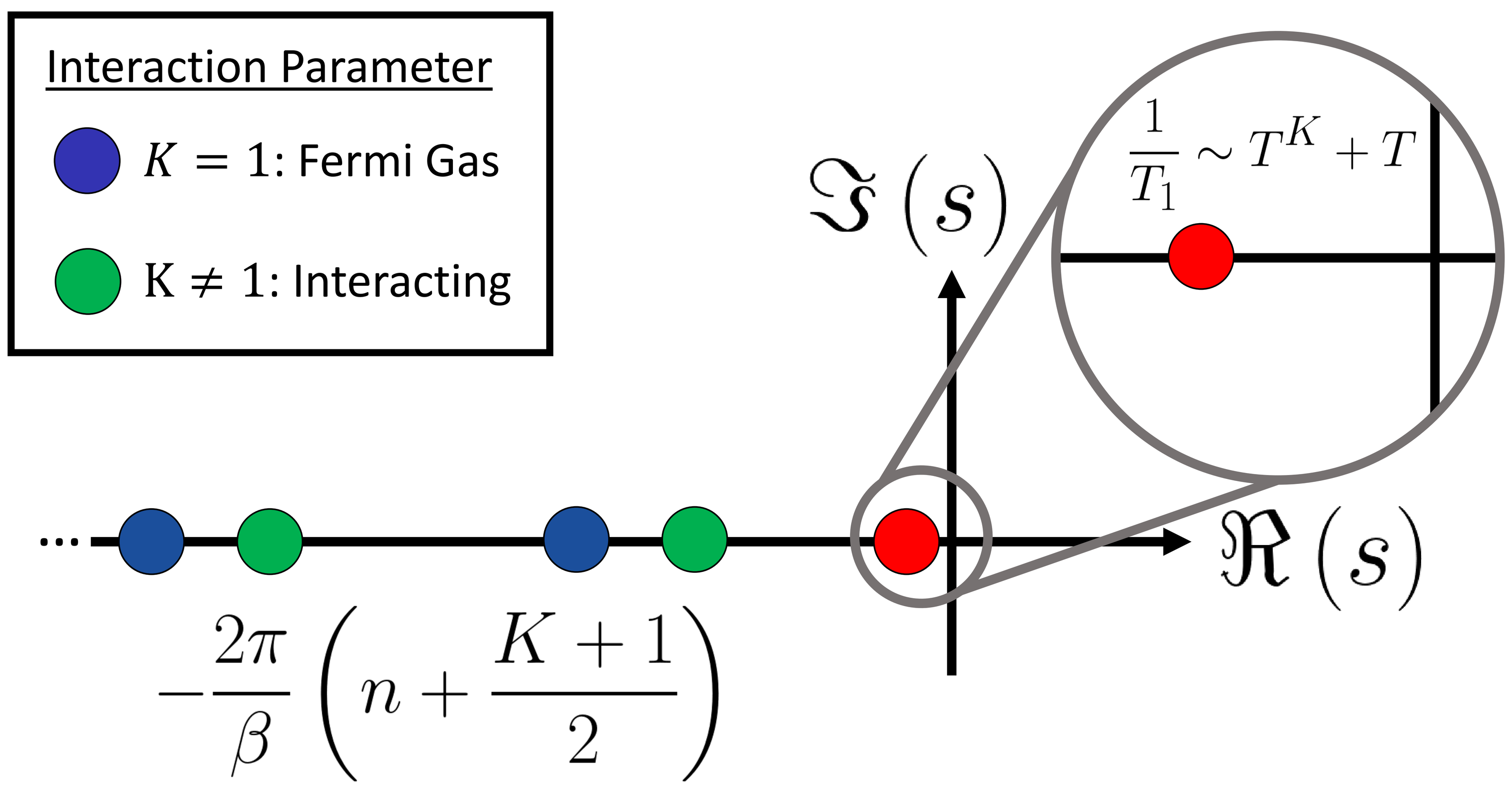


We use **Luttinger liquid** as model of a strongly correlated quantum wire ($\upsilon = \sigma, \rho$)

$$\mathcal{H}_\nu = u_\nu K_\nu (\nabla\theta_\nu)^2 + \frac{u_\nu}{K_\nu}(\nabla\phi_\nu)^2$$

We analyse **decay and oscillation modes** of impurity spin in **Laplace space**, dynamics recovered via **contour integral**.

$\rho_I(s)$:

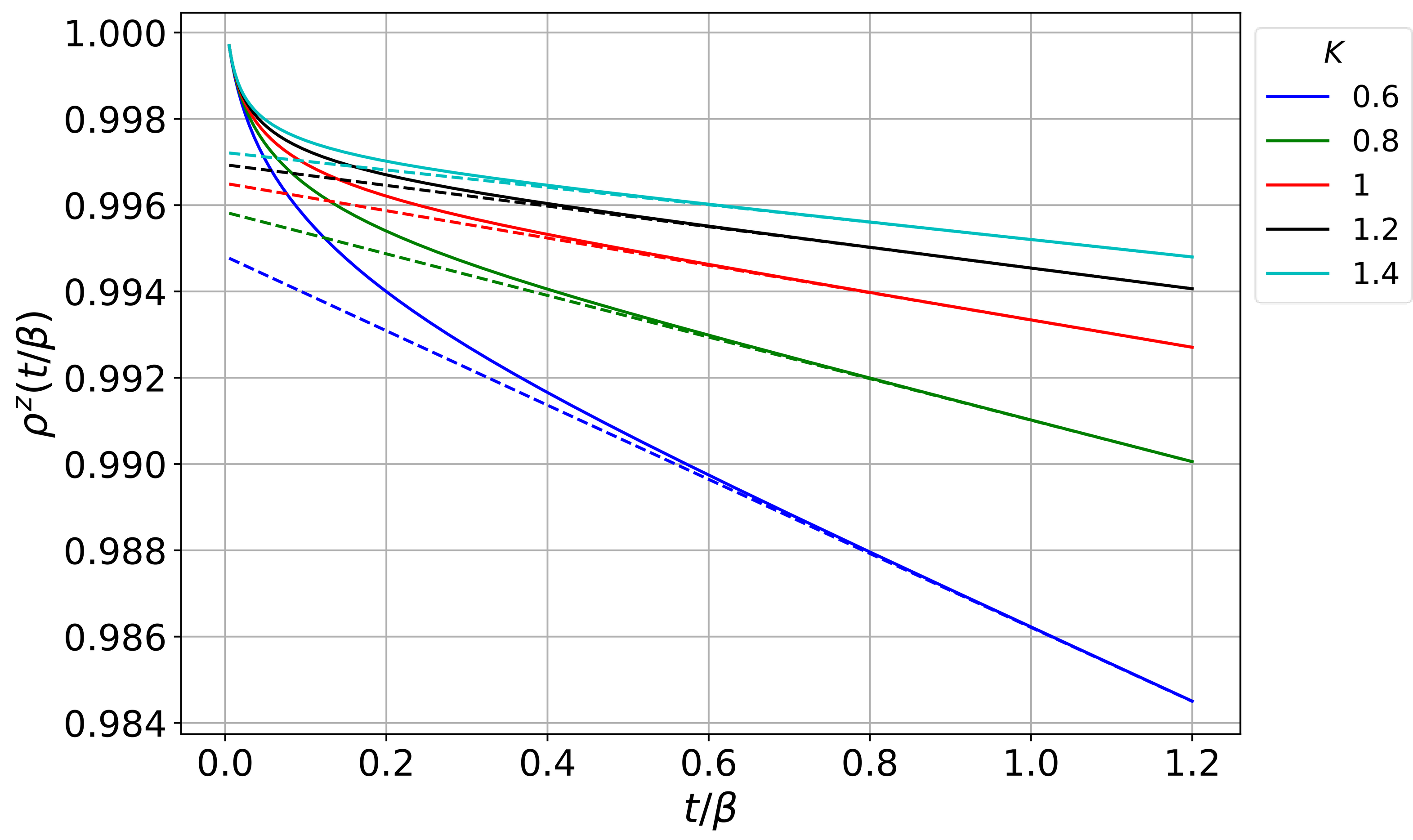


Findings

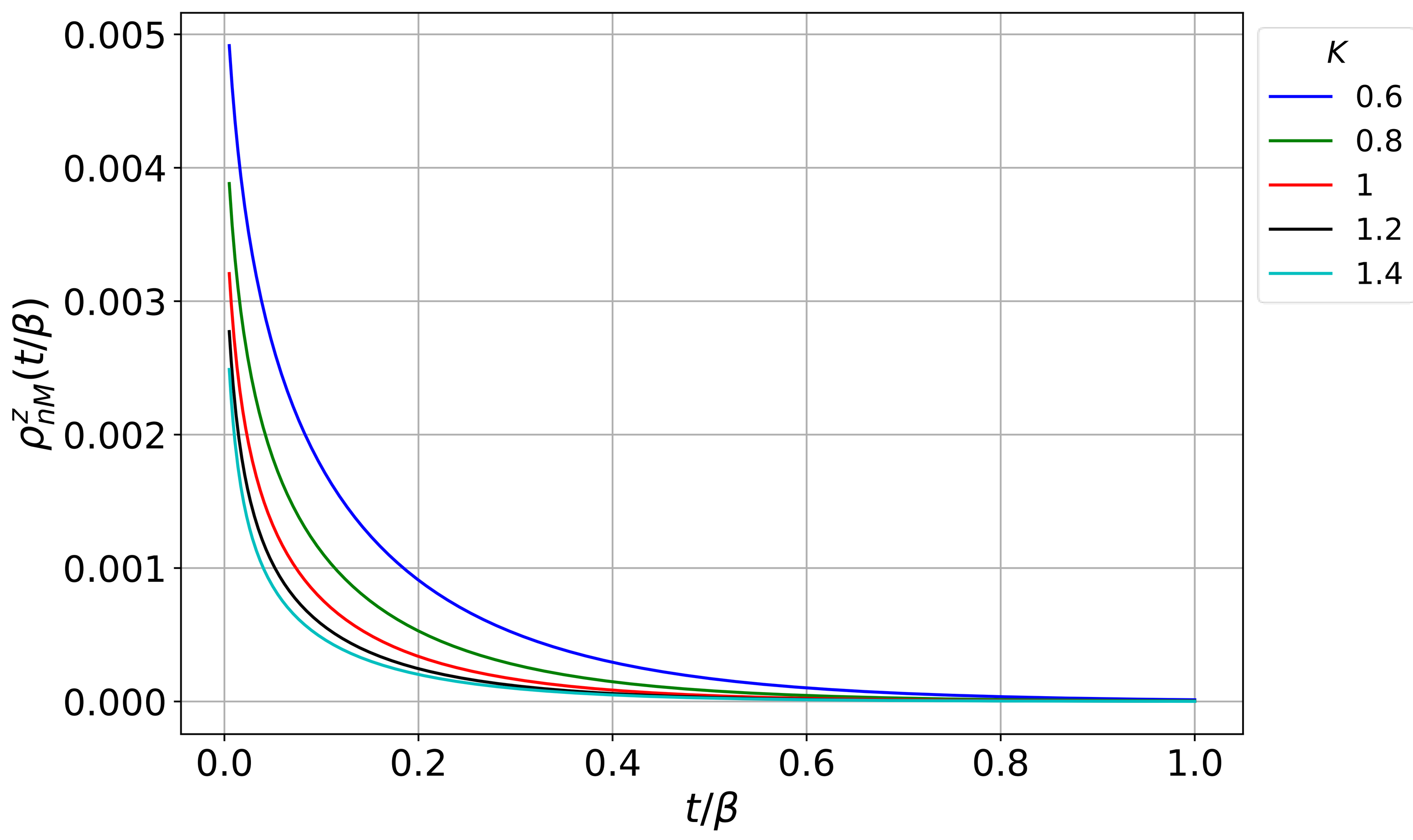
Full recovery of **modified Korringa law** through **Markov mode**.

Additional infinite sequence of **non-Markov** modes, from **dynamical feedback** of bath on spin. Retention of **Fermi-gas** modes.

Splitting of modes gives **classification** of of repulsive ($K < 1$) and attractive ($K > 1$) interactions.



Modification of initial slip amplitude and lifetime, a **new dynamical signature** of strong interactions.



Outlook

- Distil the difference in dynamical signatures between various correlated systems.
- Integrate this into a modern formulation of magnetic resonance forgoing standard high-temperature approximations, allowing for a robust description of strongly-correlated materials.

References

[1]: Slichter, CP. (1990). Principles of Magnetic Resonance. Springer.
[2]: Korringa, J. (1950). Physica, 16(7-8):601–610.
[3]: Matern, S., Loss, D., Klinovaja, J., & Braunecker, B. (2019). Physical Review B, 100(13).