Laboratoire de Physique et
Modélisation des Milieux Condensés
Univ. J. Fourier & CNRS, Grenoble, France

NEUTRONS FOR SCIENCE

Temperature can *enhance* coherent oscillations at a Landau-Zener transition

Robert S. Whitney[1,2], Maxim Clusel[2,3], Timothy Ziman[1,2]

1. LPMMC, Univ. J. Fourier & CNRS, Grenoble
2. Institut Laue Langevin, Grenoble
3. Laboratoire des Colloïdes, Verres et Nanomatériaux, Univ. Montpellier II & CNRS

Phys. Rev. Lett. **107**, 210402 (2011)

GDR Physique Quantique Mésoscopique, Décembre 2011

[1] SUMMARY

Typically: coupling to environment causes *decoherence*

...*BUT* we show that an environment can also

enhance coherent oscillations.

$\Rightarrow$ *coherent osc. grow strongly with increasing temperature*

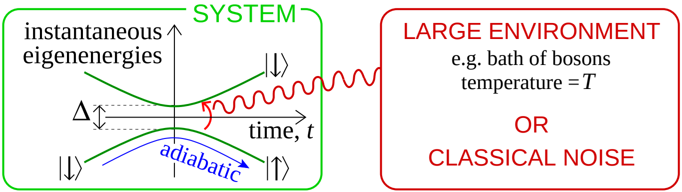
Origin in Lamb-shift $\Rightarrow$ *we call effect*

"Lamb-assisted coherent oscillations"

♣ *New probe for high-frequency environments in*

qubits, molecular magnets, etc.

[2] MODEL



System Hamiltonian: **Landau-Zener** $\mathcal{H}_t^{\rm LZ} = -\frac{1}{2}\big(\nu t\,\sigma_z + \Delta\,\sigma_x\big)$

Full Hamiltonian — system+environ.

$$\mathcal{H}_t^{\rm sys\&env} = \mathcal{H}_t^{\rm LZ} - \tfrac{1}{2}\sigma_z \mathbf{X} + \mathcal{H}^{\rm env}$$

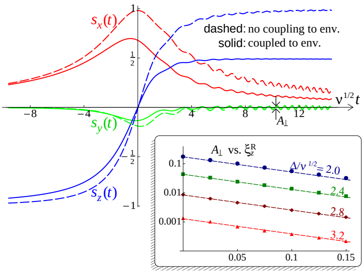
with $\mathbf{X}$ operator acting *weakly* on a *huge* number of environ. modes, $\mathcal{H}^{\rm env}$.

[3] RESULTS

(a) Decoherence and no Lamb-shift

$\Longrightarrow$ suppresses oscillations

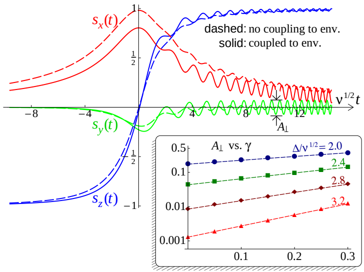
Markovian environ. (white-noise)



(b) Lamb shift and no decoherence

$\Longrightarrow$ *ENHANCES* oscillations

High-freq. environment



[4] From LAMB-SHIFT to TEMPERATURE-DEPENDENCE

"Lamb-shift = level-repulsion"

Competition between:

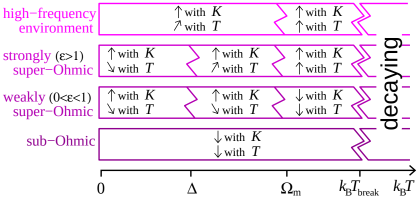
(1) Lamb-shift $\Leftarrow$ high-freq. modes reduces system gap

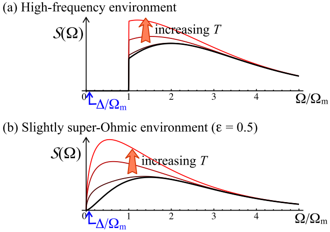
while low-freq. modes increase gap

(2) decoherence $\Leftarrow$ env. modes in resonance with system gap

$\Rightarrow$ Multiple regimes

for typical continuous spectrum of env.-modes



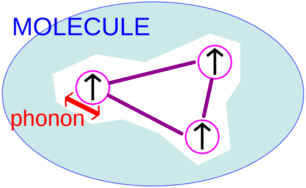


[5] MOLECULAR MAGNETS : a potential application

Solid of large molecules :

molecule = cluster of spins

enclosed by spinless atoms



Spin-interaction + symmetry of cluster

$\Longrightarrow$ ground-state = LARGE S

Spin-states *relax* at temperatures $>$ few Kelvin

Two possible scenarios for this;

(a) nuclear spins = slow $= low\text{-}freq.$

(b) phonons which *break symmetry* $= high\text{-}freq.$

Discriminate between them by studying

"Lamb-assisted coherent oscillations"

[6] DETAILS

Master equation with weak memory

$= \text{Bloch-Redfield (1957) or Nakajima-Zwanzig (1958)} \neq \text{Lindblad}$

General result: $\dot{\mathbf{s}} = \mathbf{B}_t \times \mathbf{s} + \mathbf{e}_z \times \left[\xi_t^{\mathrm{R}} \times \mathbf{s} + \xi_t^{\mathrm{I}}\right]$

with vectors $\xi_t^{\mathrm{R}}, \xi_t^{\mathrm{I}} =$ (env. coupling)$^2 \times$ functions of Env. SPECTRUM

High-frequency:

Lamb-shift only

$$\begin{pmatrix} \dot{s}_x \\ \dot{s}_y \\ \dot{s}_z \end{pmatrix} = \begin{pmatrix} 0 & \nu t & 0 \\ -\nu t & 0 & \Delta(1-\gamma) \\ 0 & -\Delta & 0 \end{pmatrix} \begin{pmatrix} s_x \\ s_y \\ s_z \end{pmatrix}$$

no analytic solution $\Longrightarrow$ numerics above

$\Longrightarrow$ Coherent osc. magnitude $\simeq (1-\gamma)^{1/2} \exp[-\Delta^2(1-\gamma)/(4\nu)]$

$\Longrightarrow$ **EXPONENTIALLY** enhanced by environ.