Heavy Quarkonia in Medium as Open Quantum Dissipative System.

A Wave Function based Approach..........

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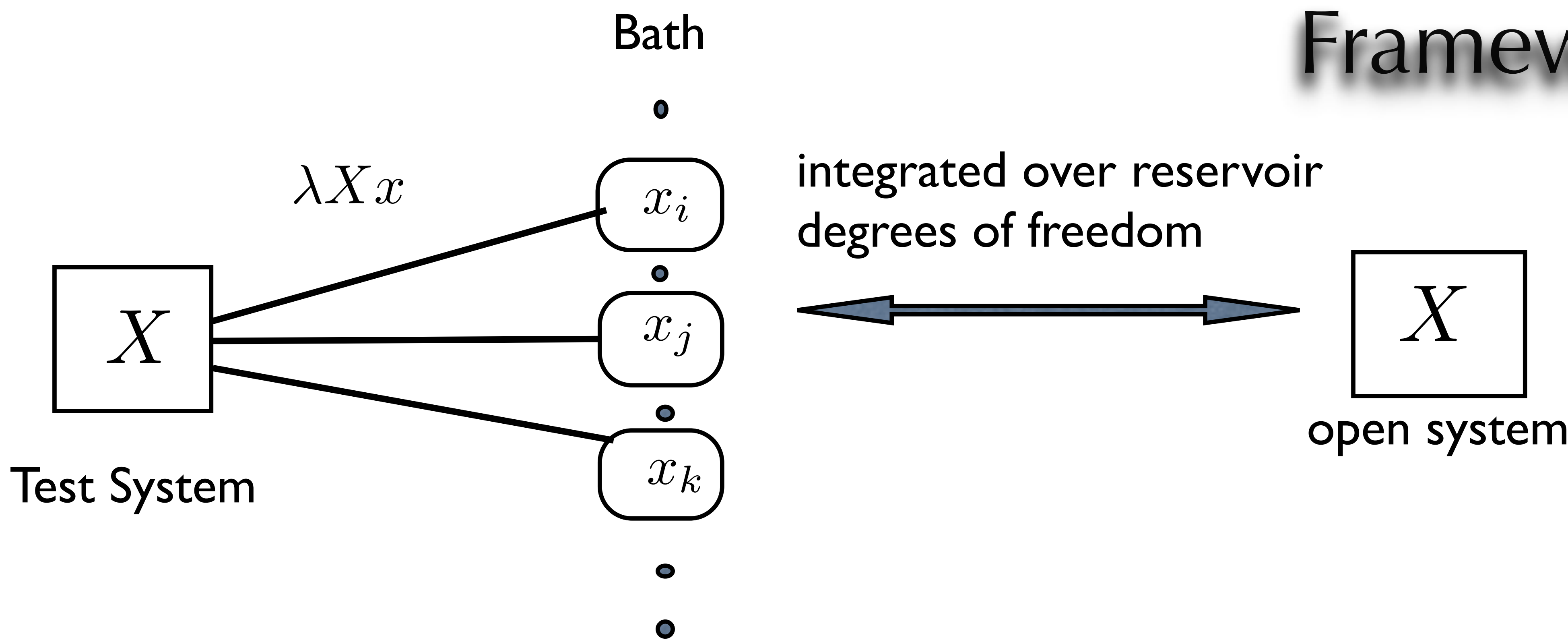
The Model

- Heavy Quarkonia (a small System) immersed in large system (QGP).
- The QGP medium can be seen as a reservoir which exchanges energy and momentum with the small system without being noticeably affected.

Framework



Evolution of quarkonia in medium is similar to the dynamics of an open Quantum Dissipative System.

Features

- Population of initial bound state decays with time.
- Accounts for the possible transitions between different states.

Different Approaches

- Feynman-Vernon Theory of Influence Functional.

(Restricted to some simple cases as far as calculability is concerned.)

- Master equation approach.

(Perturbative approach appropriate within weak coupling)

- Quantum Jump Approach (Monte-Carlo wave function).

(Numerical Solution of Stochastic Schrödinger Equation.)

Wave Function Based Approach

Transition Amplitude from $\Psi \rightarrow \Psi'$

$$\langle \Psi | \Psi' \rangle = \int dX dX' \Psi'(X') \Big(\underbrace{\sum_{i,f} \int dx_1 dx'_1 .. dx_j dx'_j \Phi_f(x'_1, x'_2 .. x'_j.) K \Phi_i(x_1, x_2 .. x_j.)}_{\text{Effective Propagator of the Test System}} \Big) \Psi(X)$$

- Φ stays in the tensor product space formed by the state spaces of members of the medium.

- K is the Propagator of the System + Medium.

Exploratory Model

- The simplest case is a Harmonic Oscillator (test system) in a Medium.

$$L = L_T + L_B + L_I$$

- The Medium is modeled as a collection of a large number of Harmonic Oscillators.

- The interaction of each oscillator of the medium with the test system is bilinear.

$$L_I = -\lambda X x$$

For QUARKONIA as well

- The 4 Dimensional generalization of the test Oscillator (with a constraint) corresponds to the short range part of the $Q\bar{Q}$ potential (in vacuum) in 3-D.

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☑ **The framework is applicable to describe the real time dynamics of quarkonia in QGP.**

Thermal medium

- The wave function based approach is a very general one. It is valid for zero temperature and for finite temperature, as well as for a medium out-of-equilibrium.

- To implement the temperature (with the real time dynamics), we just have to take care of the thermal distribution of the modes in the medium.

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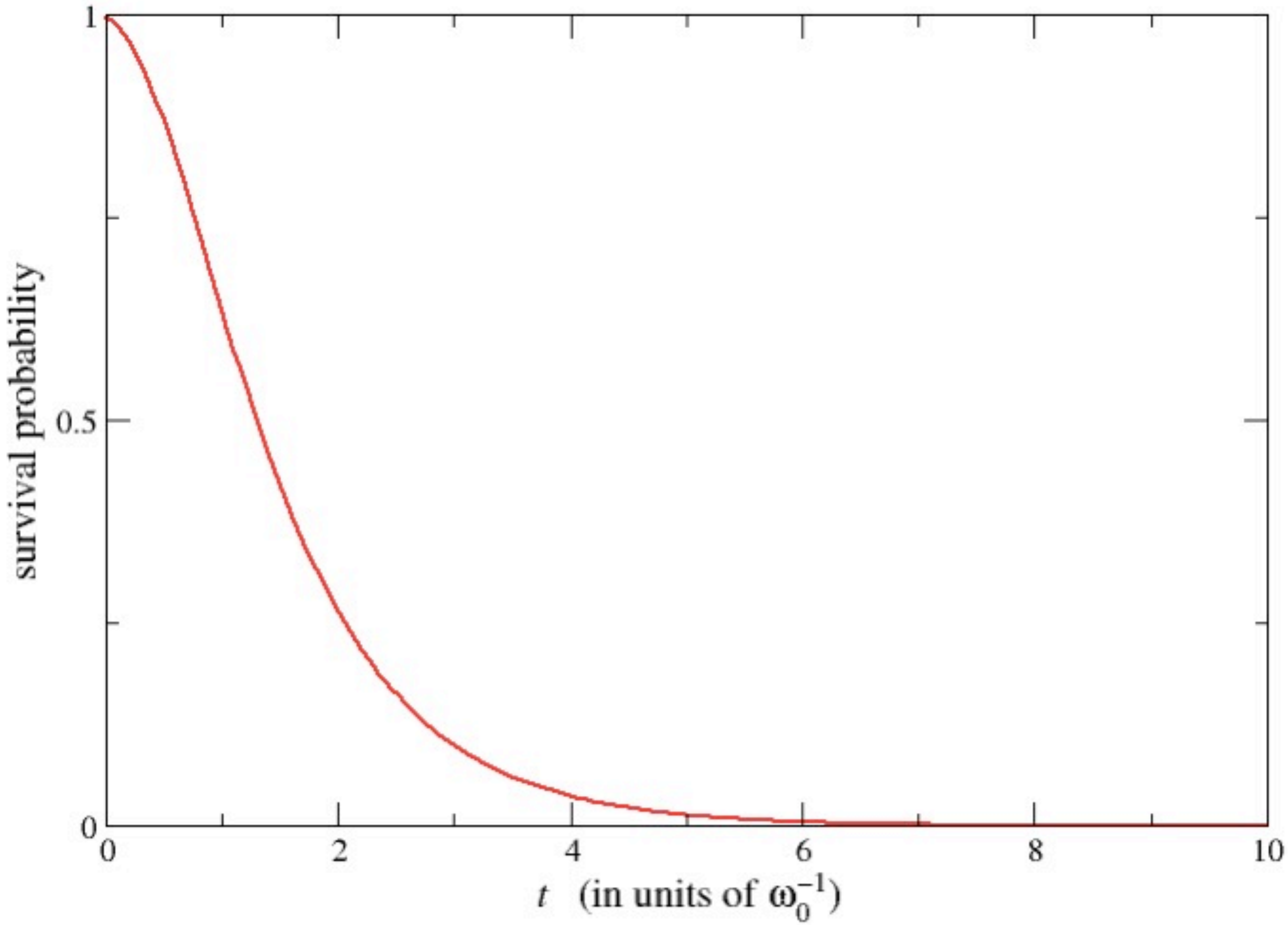
- Gluons with much bigger wavelength compared to the dipole size feel the object as color neutral and leave it unaffected.

Comparable Modes

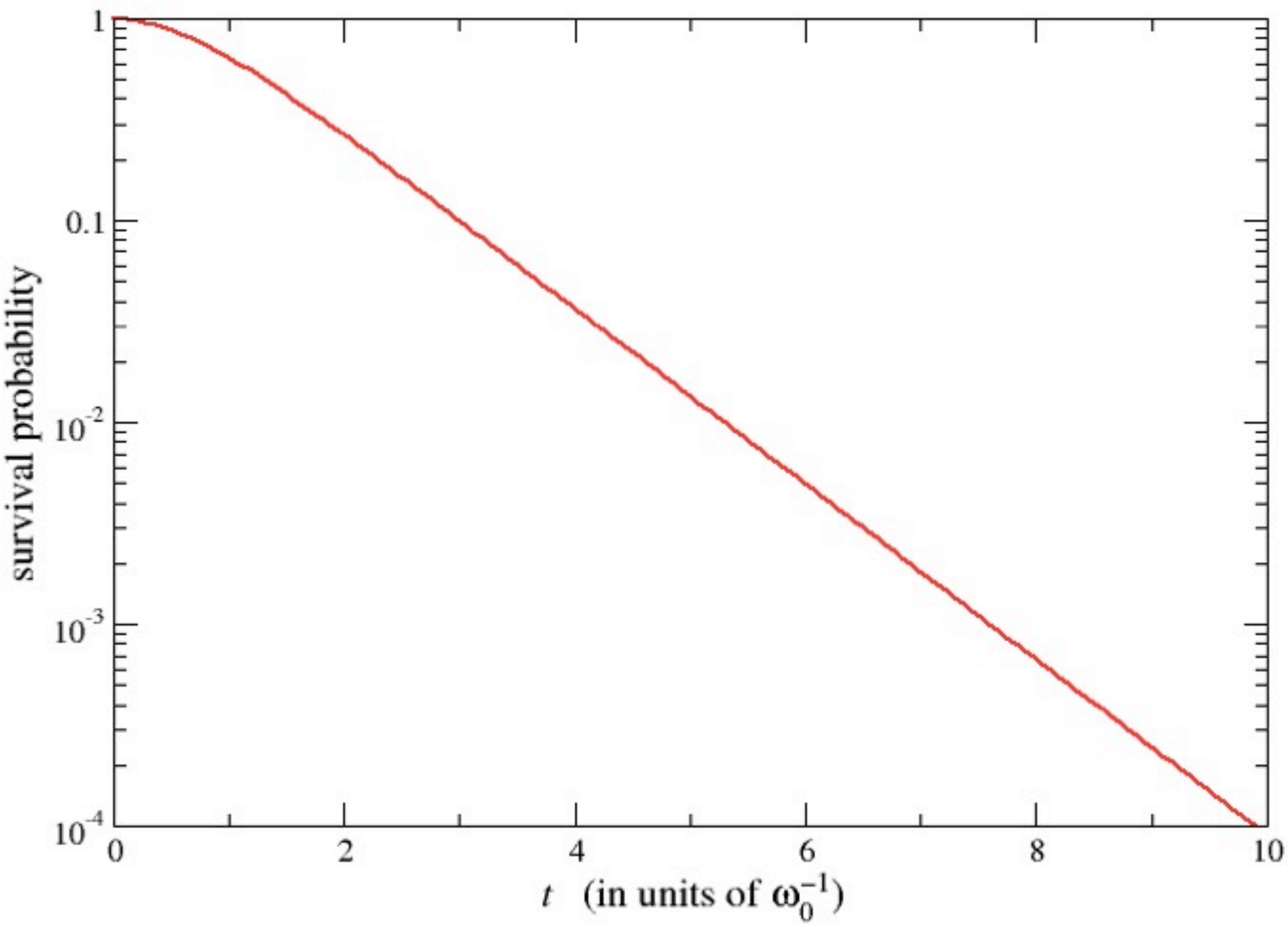
Linear Plot



Bath modes with frequencies comparable to ω_0

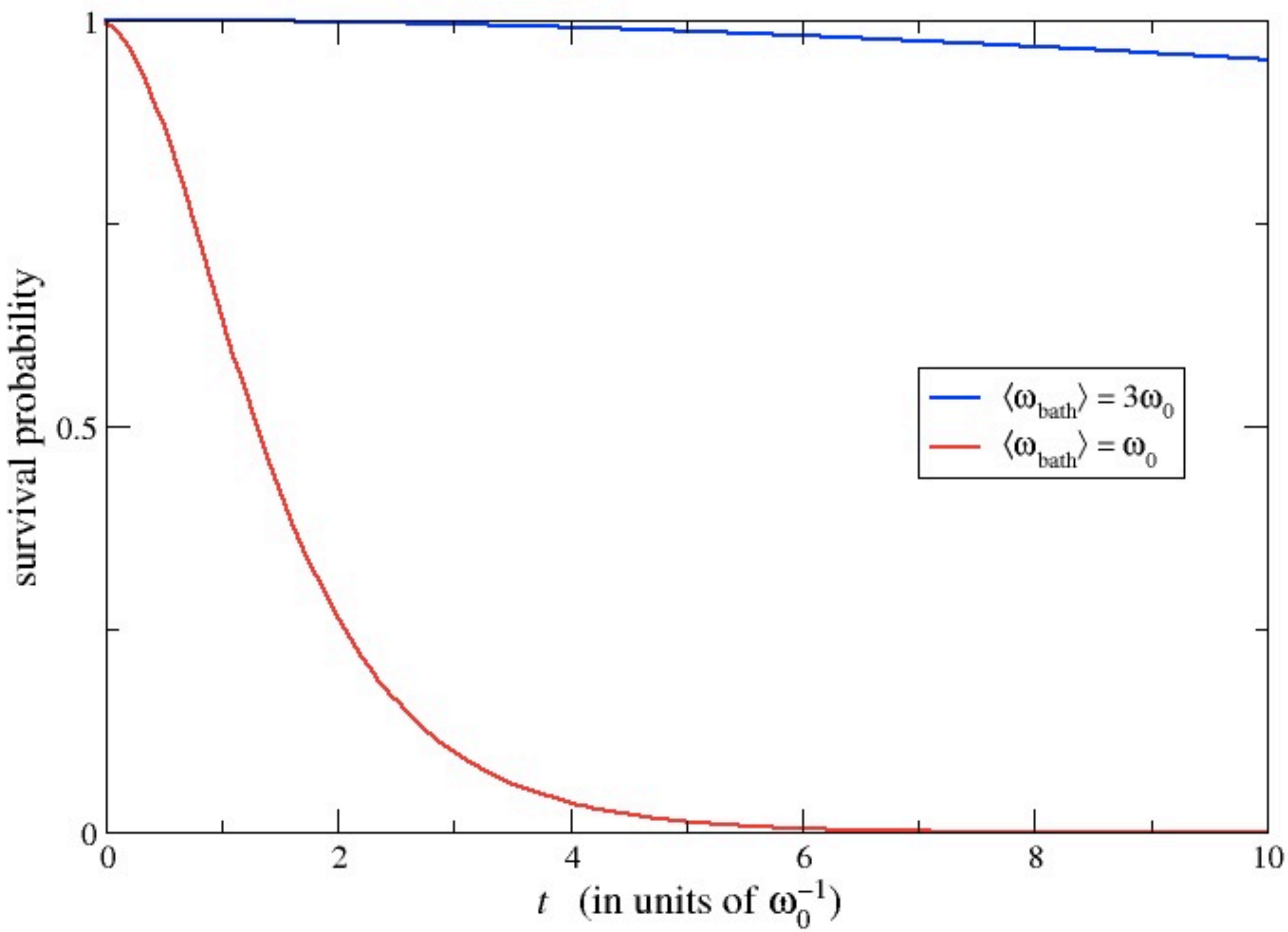
Comparable Modes

Log plot



Bath modes with frequencies comparable to ω_0

Distant Modes Effects



Bath modes with frequencies distant from ω_0

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- The approach is very general.......

1. It is non perturbative. Does not assume any thing about the coupling strength.
2. Assumes nothing about the bath property. Applies to thermal and non-thermal baths.
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- Proper Expected Behavior........
    1. Dissociation.
    2. Highly energetic gluons do not trigger the transition.

Prospects

- First step: Generalization of the test system to a 4-D constrained Harmonic Oscillator, which corresponds to the real system (quarkonium).
(*Kustaanheimo-Stiefel transformation*)

- Making contact with other different approaches.

1. With the Effective Field Theory.
(*In terms of an effective propagator and potential*)

2. With the Master Equation Approach.
(*In terms of Dissipative Dynamics*)

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