Presented by Guillaume Hupin

Methods to solve correlated systems : Stochastic approach

Goal : Solve correlated quantum systems such as Nuclei by using a new approach. Firstly, applied to open quantum systems.

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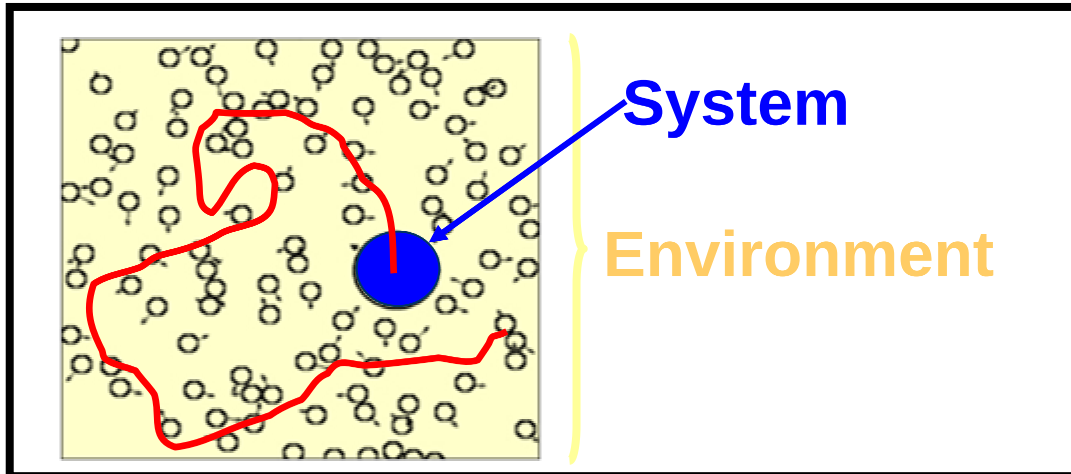
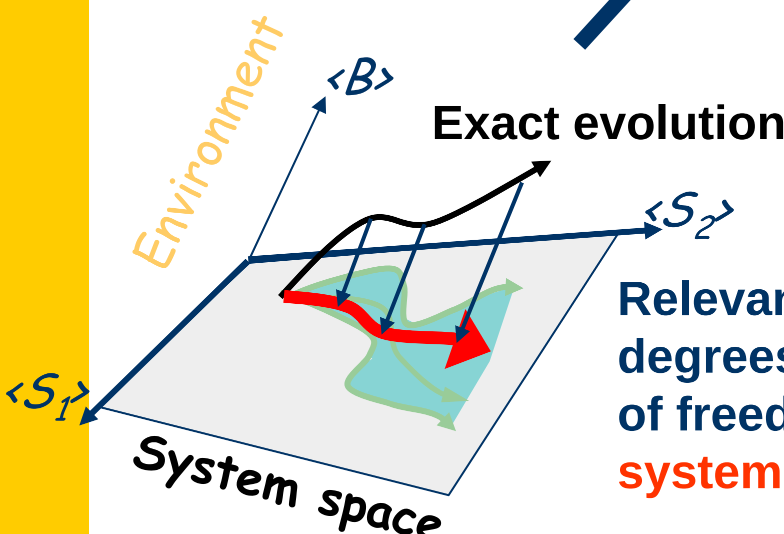
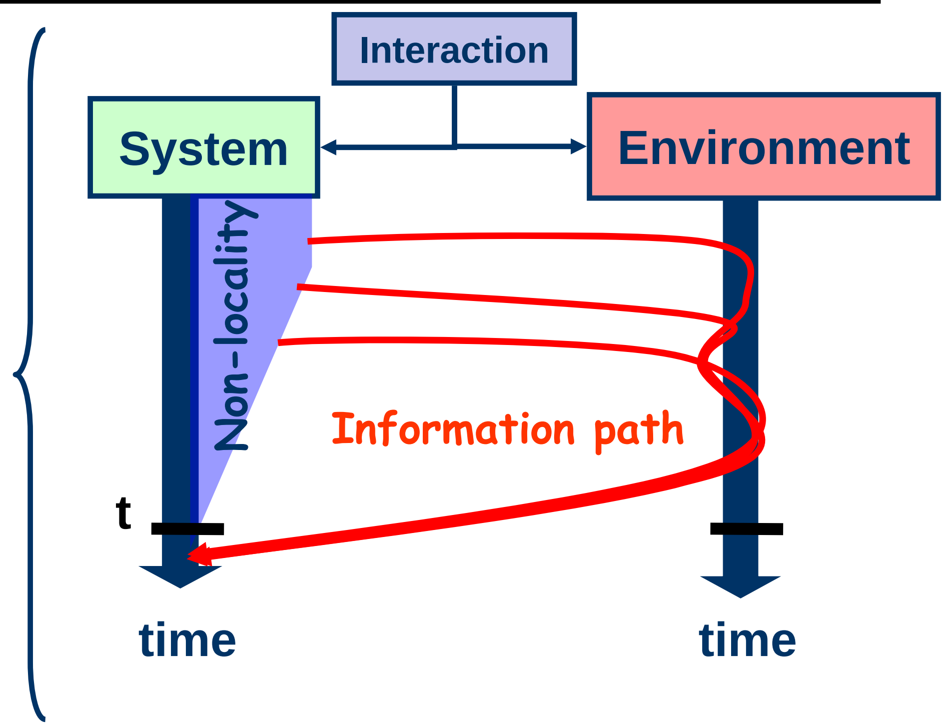
Introduction to open quantum systems

R. Brown, (1827).





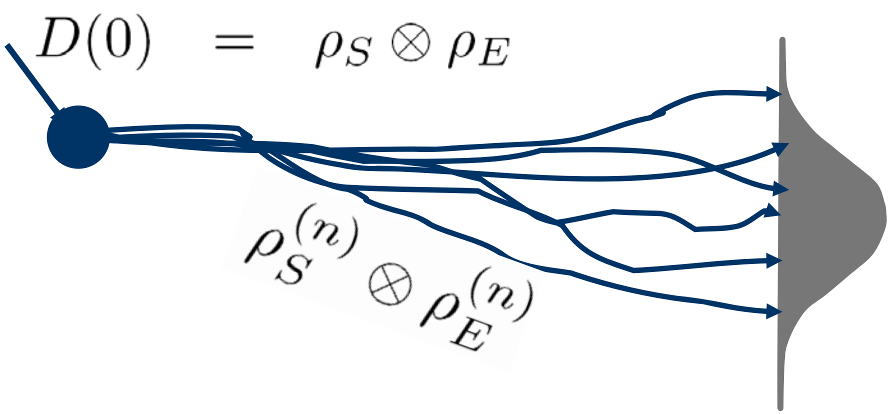
Relevant degrees of freedom: system

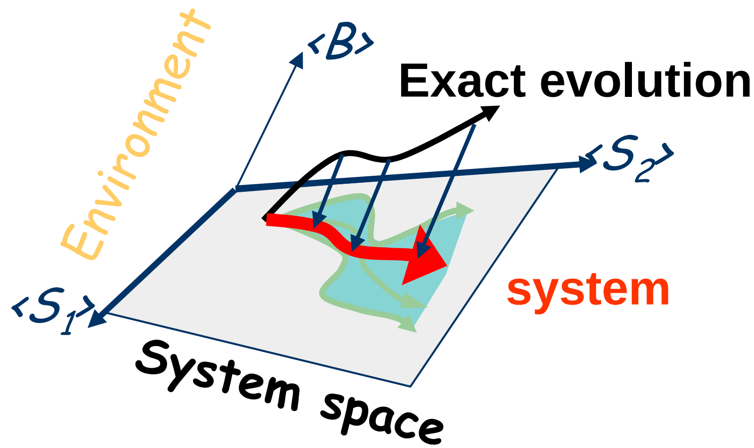


Stochastic formulation for reduced dynamic

The system density can be written as an average :

$$\boxed{D_{exact}(t) = \sum_n \Lambda_n \, \rho_S^{(n)} \otimes \rho_E^{(n)}}$$





Langevin equation :

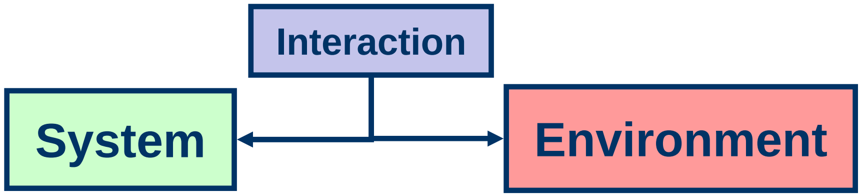
Deterministic part

Noise part plays a diffusion rôle

$$d\tilde{X}_i^n = G_i[\vec{X}^{(n)}(t), .., \vec{X}(t), t]dt + B_{i,j}(\vec{X}(t))dW_j(t)$$

Open quantum mechanics

Denis Lacroix, Physical Review E (2008)



$$H = H_S + H_B + Q \otimes B$$

Langevin eq. determinist part

Langevin eq. diffusion part

- Liouville von Neumann equation :

$$i\hbar \frac{dD}{dt}(t) = [H, D(t)]$$

- Equivalent Stoch. Density Eq. :

$$\overline{d\xi_S d\xi_E} = \frac{dt}{i\hbar}$$

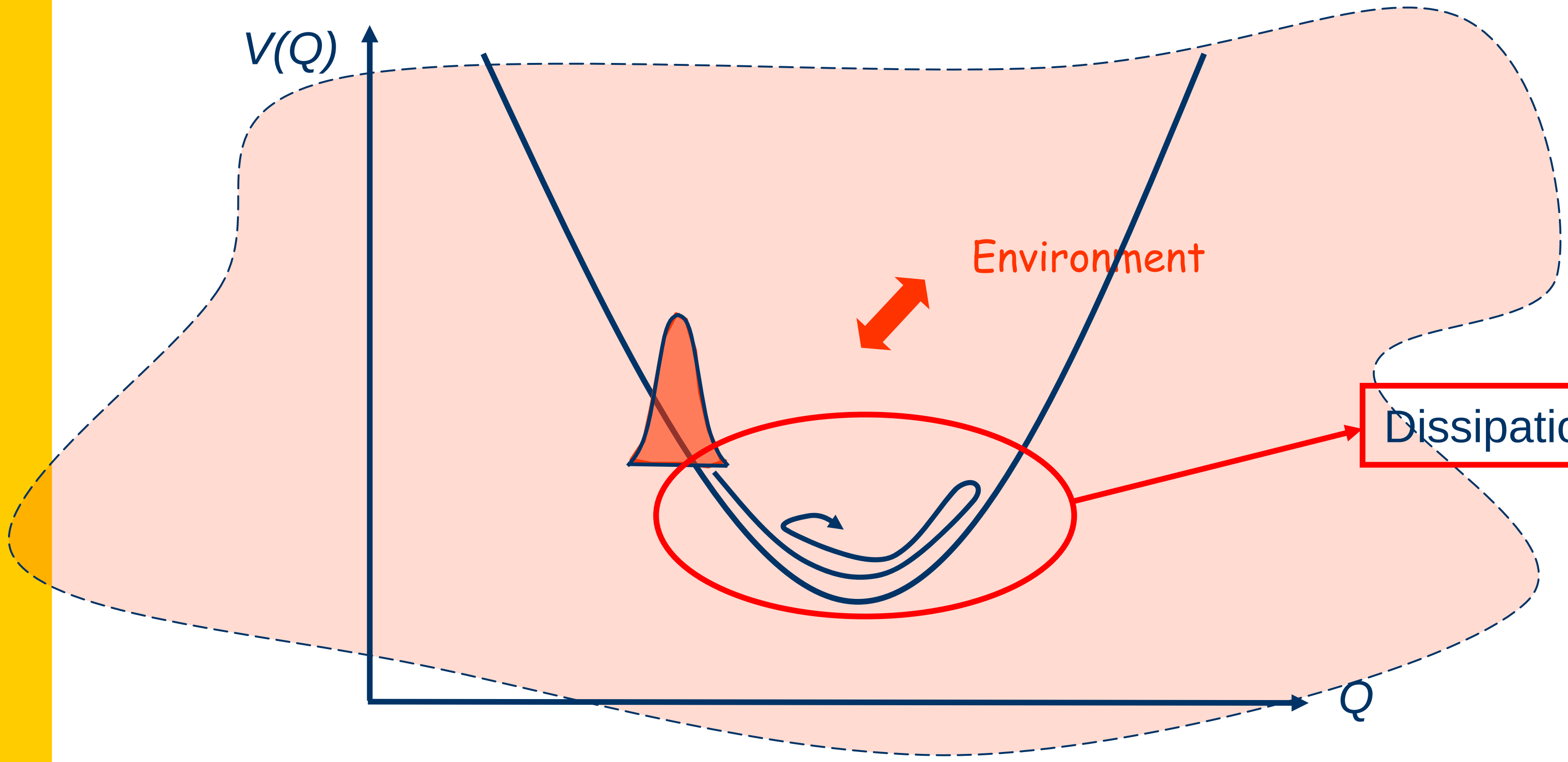
$$\overline{d\lambda_S d\lambda_E} = -\frac{dt}{i\hbar}$$

$$d\rho_S(t) = \frac{dt}{i\hbar}[H_S, \rho_S(t)] + d\xi_S \; Q\rho_S(t) + d\lambda_S \; \rho_S(t) Q$$

$$d\rho_B(t) = \frac{dt}{i\hbar}[H_B, \rho_B(t)] + d\xi_E \; B\rho_B(t) + d\lambda_E \; \rho_B(t) B$$

Applications to open quantum systems

1. This method has been applied to spin boson model.
2. M2 internship work : Application to the Caldeira Leggett model.



Application : Caldeira Leggett model

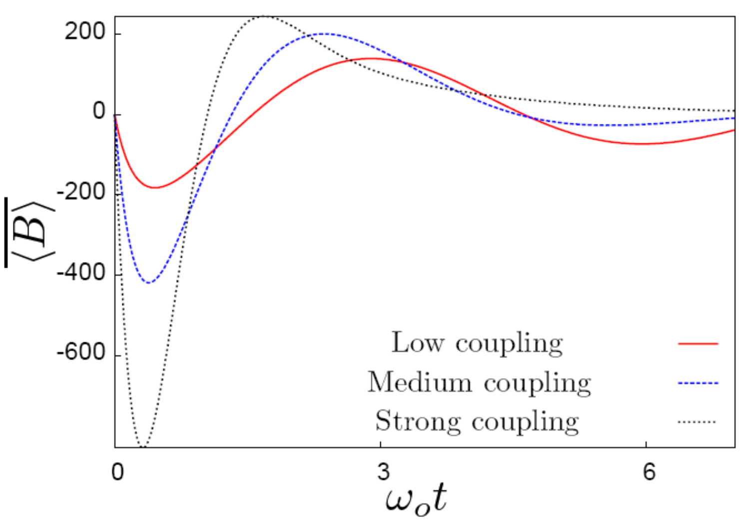
Observable expectation values are given by

$$d\langle P\rangle = -m_O\omega_O^2\langle Q\rangle dt - \langle B\rangle dt + 2du_S\sigma_{PQ} - \hbar dv_S$$

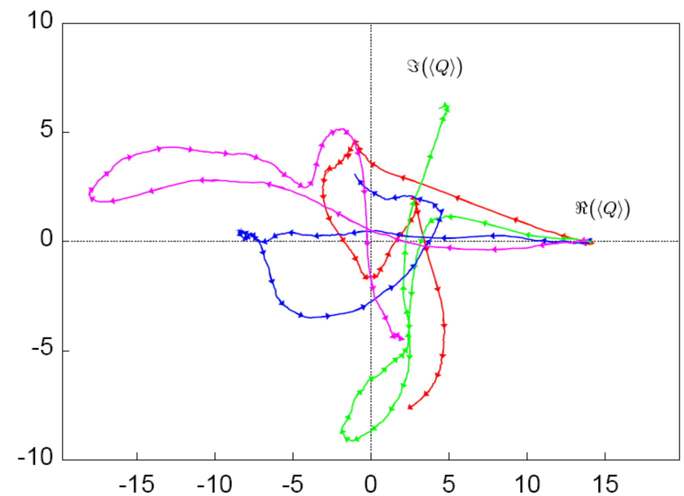
$$d\langle Q\rangle = \frac{\langle P\rangle}{m_O}dt + 2du_S\sigma_{QQ}$$

Random part

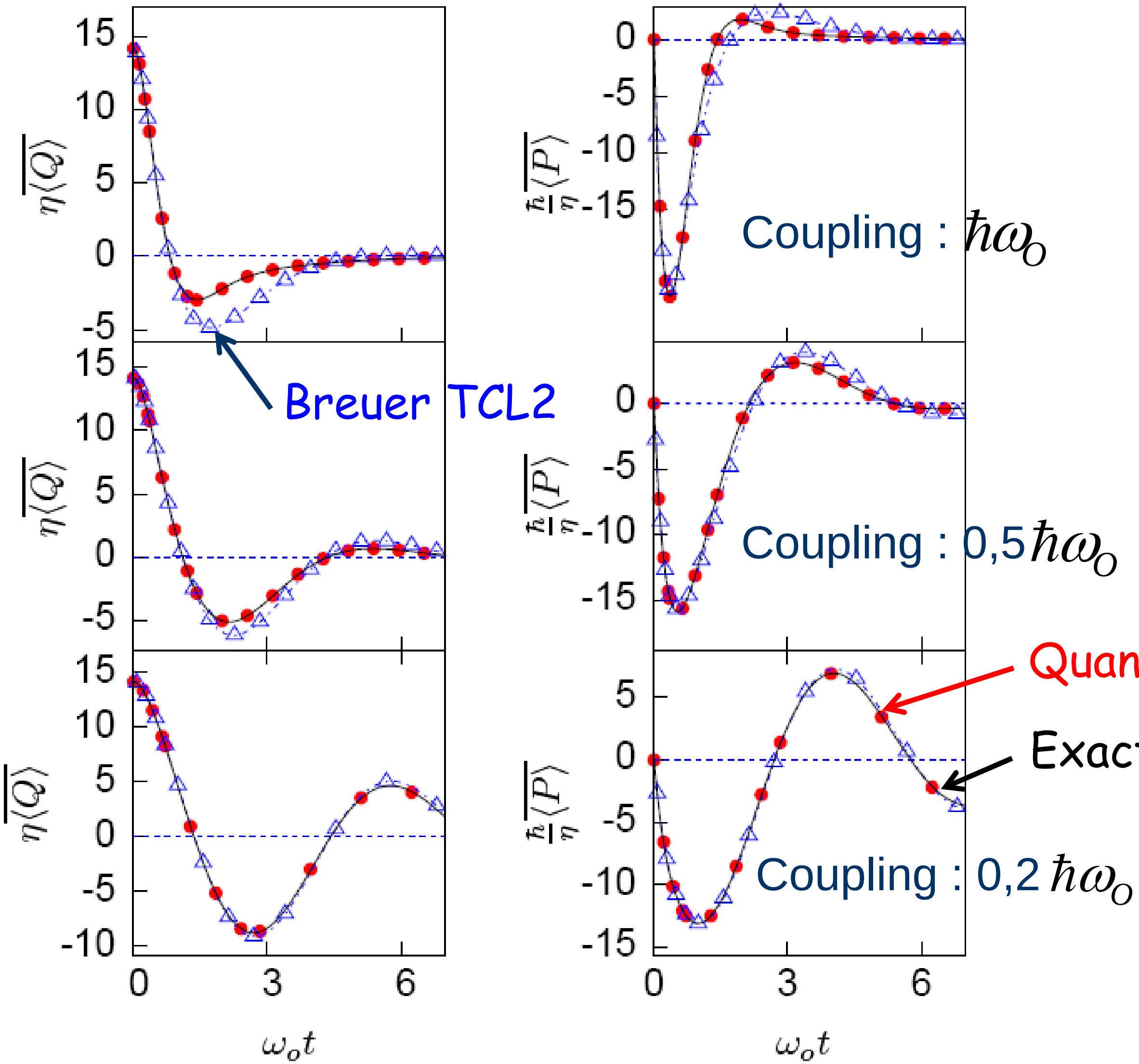
1° Average evolution of the bath observable B



2° Expectation values of Q and P in the complex plane



Evolution of the first moments



Using a Drude spectral density:

$$J(w) = \frac{\eta\, 2m_O}{\pi} w \frac{\Omega^2}{w^2+\Omega^2}$$

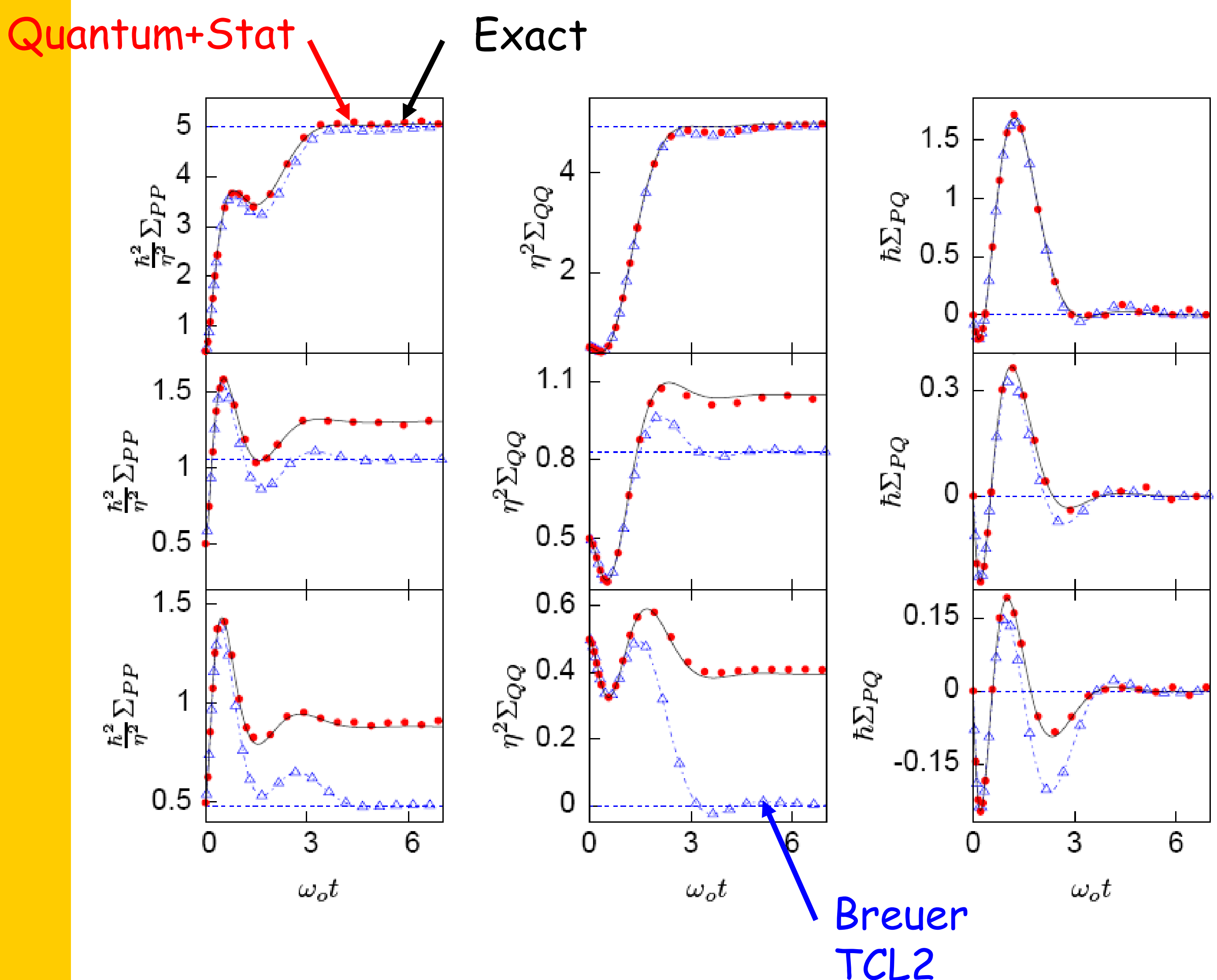
$$\Omega = 5\hbar\omega_O$$

$$\hbar\omega_O = 14 MeV$$

T = $\hbar\omega_O$

2^{nd} moments evolution

Coupling : 0,5$\hbar\omega_o$



T : 5 $\hbar\omega_o$

T = $\hbar\omega_o$

T : 0,1 $\hbar\omega_o$

Applications to open quantum systems

1. This method has been applied to spin boson model.
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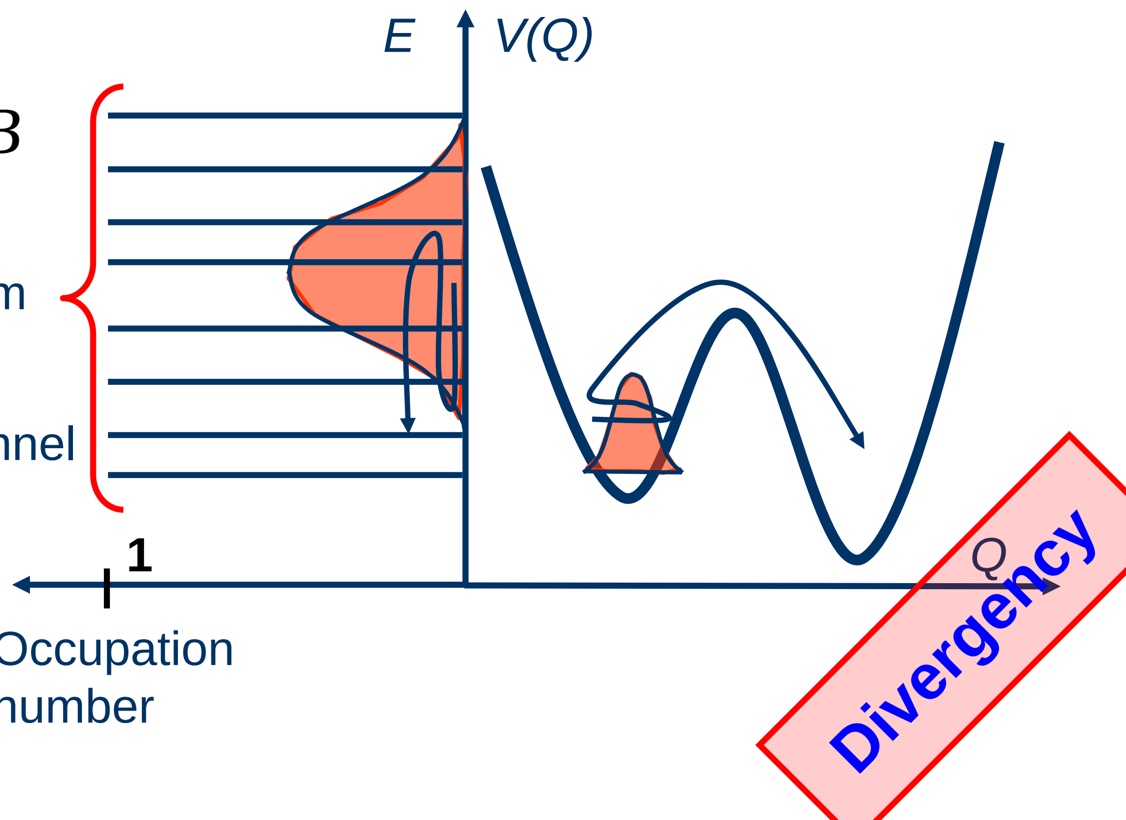
3. Last three month : Application to any kind of potential with different methods

$$H = H_S + H_B + Q \otimes B$$

Eigenstates of the system alone

- Coupled channel



Applications to open quantum systems

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Quantum+Statistical fluctuations

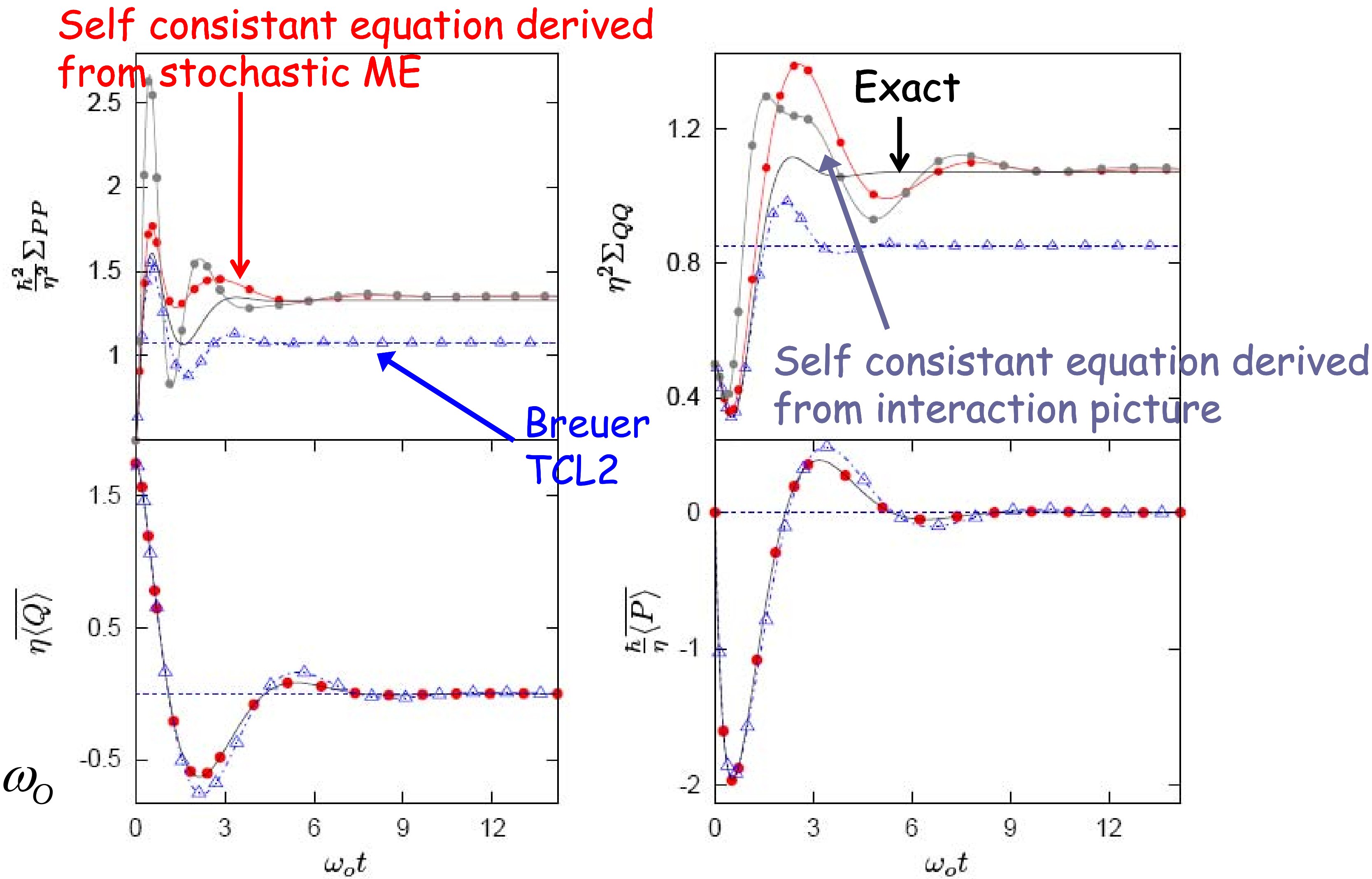
$$\Sigma_{QQ} \equiv= \overline{\langle Q^2 \rangle} - \overline{\langle Q \rangle}^2 = \sigma_{QQ} + \overline{\langle Q \rangle^2} - \overline{\langle Q \rangle}^2$$

$$\begin{aligned} \overline{\langle Q \rangle \langle B \rangle} - \overline{\langle Q \rangle}\, \overline{\langle B \rangle} &= -\frac{1}{\hbar}\int_0^t D(t-s)ds \left(cos(\omega_o(t-s))S_{QQ}(s) - sin(\omega_o(t-s))\frac{S_{PQ}(s)}{m_o\omega_o} \right) \\ &- \frac{1}{2}\int_0^t \frac{ds}{m_o\omega_o} D_1(t-s) sin\left(\omega_o\left(t-s\right)\right) \end{aligned}$$

+ higher order

- Self consistant calculation

Self consistant calculation : for harmonic oscillator



T = $\hbar\omega_o$

Coupling : 0,5$\hbar\omega_o$

Conclusion & perspective

- A new formulation has been obtained with the help of stochastic approach.
- Experience on memory kernel, numerical simulation & computation acquired.
- Introduction on open quantum theory.

- Find a way to get convergence of the stochastic approach?
- Application to the N body problem.