Összefonódás Hirtelen Halála

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Tartalom

Már értem az összefonódást ... ?

- Melyik összefonódott:

$$\Psi(x,y) = \begin{cases} \psi_A(x)\psi_B(y) \\ \psi_A(x)\psi_B(y) + \psi_A(y)\psi_B(x) \end{cases}$$

  ha x, y koordináták
  - egyetlen 2D részecskéi
  - két megkülönböztethető 1D részecskéi
  - két bozonéi
- Lehet-e egyszerre három A, B, C rendszer is 'nagyon' összefonódva?
- Egy átlagos S rendszer össze van-e fonva a Univerzum Többi Részével?
- Hogyan lehet S-et szétfonni UTR-től?

Hogyan lehet S-et szétfonni UTR-től?

Ugrásszerűen, azonnal?

- Projektív kvantum méréssel

$$\hat{\rho} \Longrightarrow \sum_{\lambda} \hat{P}_\lambda \hat{\rho} \hat{P}_\lambda, \qquad \hat{P}_\lambda = |\lambda\rangle\langle\lambda|\,, \quad \{|\lambda\rangle\} \text{ TONR}$$

- Szétfonó méréssel (Holevo 1999; Shor,Ruskai 2002)

$$\hat{\rho} \Longrightarrow \sum_{\lambda} \hat{\rho}_\lambda \,\mathrm{tr}\left[\hat{\rho}\hat{P}_\lambda\right], \qquad \hat{P}_\lambda \geq 0, \quad \{\hat{P}_\lambda\} \text{ POVM}$$

És dinamikailag, de véges idő alatt?

- Zajjal (Diósi 2002; Dodd,Halliwell 2003)
- Spontán emisszióval (Eberly,Yu 2004)

Az összefonódás hirtelen halála

Stacionér nyitott (irreverzibilis) kvantumrendszerben

- Disszipatív csillapodás: exponenciális
- Fázisvesztés (dekoherencia): exponenciális
- Szétfonódás: véges idejű

Hogy bizonyos kvantumtulajdonságok véges idejűek, ismert volt korábbról (Diósi 1987, Khalfin-Tsirelson 1992, Diósi-Kiefer 2002). Az "összefonódás hirtelen halála" elnevezés Yu és Eberly leleménye, a részletes kutatás megkezdése az ő érdemük.

• Diósi L 2002 Total disentanglement by Markovian open system dynamics, International Workshop DICE2002, http://www.rmki.kfki.hu/∼diosi/slides/dice2002.pdf
•Diósi L 2003 Progressive decoherence and total environmental disentanglement, LNP 622, 157
•Dodd PJ, Halliwell JJ 2004 Disentanglement and decoherence by open system dynamics, PRA 69, 052105
•Yu T, Eberly JH 2004 Finite-time disentanglement via spontaneous emission PRL 93, 140404
•Yu T, Eberly JH 2009 Sudden death of entanglement, Science 323, 598

~~Intrinsic Time in Markovian Open Systems~~ 1

Total Disentanglment by Markovian Open System Dynamics

(Lajos Diósi, Budapest)

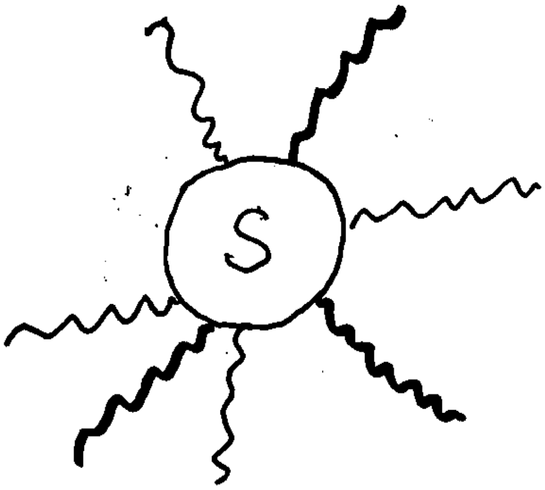
- von Neumann-measurement
- Disentanglment
- — " — of qbits
- — " — of particles
  - Wigner function ≥ 0
  - P-function ≥ 0

in finite time

- Conclusion

Piombino, 3 Sept 2002

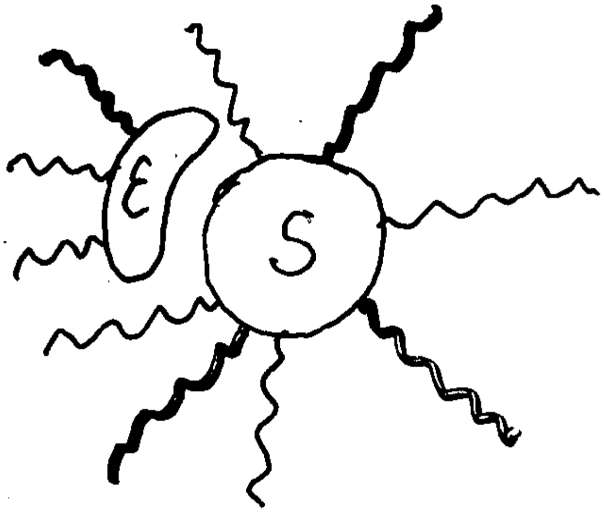
1a



$t < 0$

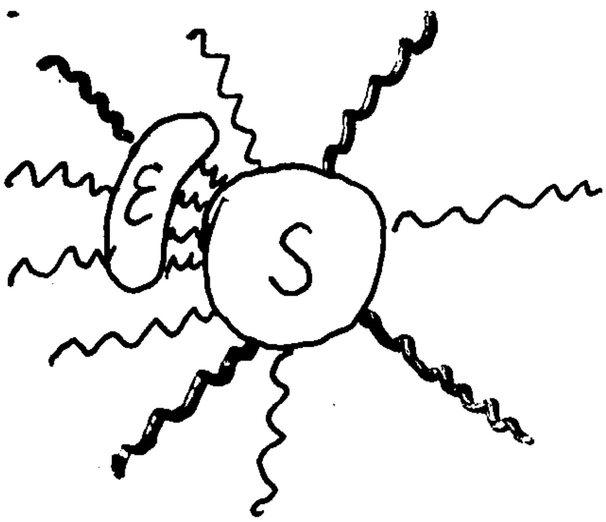
classical correlation

quantum correlation



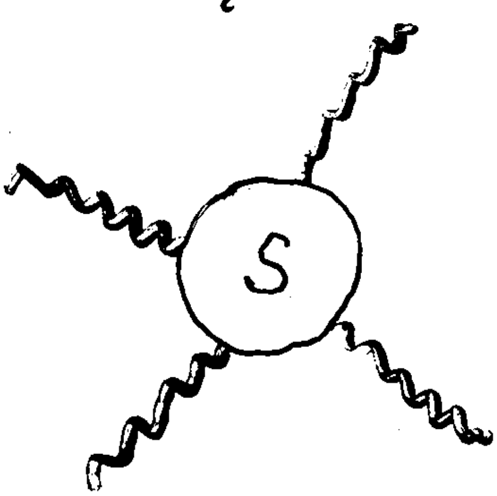
$t = 0$

System
Environment
Rest Of Universe



$$\frac{d}{dt}\hat{\rho}_S = \mathcal{L}\hat{\rho}_S$$

$$t \in [0, t_D']$$



$$t > t_D$$

$$\hat{\rho}_{S+ROU} = \sum_\lambda p_\lambda \hat{\rho}_S^\lambda \otimes \hat{\rho}_{ROU}^\lambda$$

$$p_\lambda \geq 0 ; \sum_\lambda p_\lambda = 1$$

Von Neumann-measurement

$$\hat{\rho} \longrightarrow \sum_\lambda \hat{P}^\lambda \hat{\rho} \hat{P}^\lambda \qquad \hat{P}^\lambda > 0,\ \sum \hat{P}^\lambda = \hat{I} \quad [\hat{P}^\lambda, \hat{P}^\mu] = 0$$

attributes objective classical properties to the post-measurement state.

The diagonal form

$$\hat{\rho} = \sum_\lambda \hat{P}^\lambda \hat{\rho} \hat{P}^\lambda$$

in itself wouldn't be enough since $\hat{\rho}$ may still be q-correlated with ROU.

This is not in vN's book:

$$\hat{\rho}_U \longrightarrow \sum_\lambda (\hat{P}^\lambda \otimes \hat{I}_{ROU}) \hat{\rho}_U (\hat{P}^\lambda \otimes \hat{I}_{ROU})$$

but should be understood!

vN measurement diagonalizes & disentangles*

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* to the extent needed for objective classical prop's.

Local maps that disentangle

Definition: $\hat{\rho}$ is disentangled from the RestOftheUniverse if

$$\hat{\rho}_U = \sum_\lambda p_\lambda \hat{\rho}^\lambda \otimes \hat{\rho}^\lambda_{ROU}$$

$$p_\lambda > 0, \ \sum_\lambda p_\lambda = 1$$

Theorem: $\hat{\rho} \to \mathcal{M}\hat{\rho}$ disentangles all $\hat{\rho}$ from the RestOftheUniverse iff

$$\mathcal{M}\hat{\rho} = \sum_\lambda \hat{\rho}_\lambda \, tr(\hat{P}^\lambda \hat{\rho})$$

M. Horodecki, Shor (2002)

$$\hat{P}^\lambda \geq 0, \ \sum_\lambda \hat{P}^\lambda = \hat{I} \quad \text{i.e.: } \{\hat{P}^\lambda\} \equiv POVM$$

Markovian disentanglement of spin-$\frac{1}{2}$

$\hat{\rho}(0)$ arbitrary, maybe entangled with ROU

"free" spin in isotropic bath $\quad \frac{d}{dt}\hat{\rho} = \frac{1}{4}\hat{\vec{\sigma}}\hat{\rho}\hat{\vec{\sigma}} - \frac{3}{4}\hat{\rho}, \qquad t \geq 0$

$$\rightsquigarrow \hat{\rho}(t) \equiv \mathcal{M}(t)\hat{\rho}(0)$$
$$= \frac{1}{2}\left[\hat{I} + e^{-t}\hat{\vec{\sigma}}\,\mathrm{tr}\left[\hat{\vec{\sigma}}\hat{\rho}(0)\right]\right]$$

$\mathcal{M}(t)$ totally disentangles from ROU

iff

$$\mathcal{M}(t)\bullet = \sum_\lambda \hat{\rho}^\lambda\,\mathrm{tr}(\hat{P}^\lambda\bullet)$$

Try this: $\lambda = (\alpha, s)$; $\alpha = x, y, z$; $s = \pm 1$

$$\hat{\rho}^{(\alpha,s)} = \frac{1}{2}\left(\hat{I} + 3se^{-t}\hat{\sigma}_\alpha\right)$$
$$\hat{P}^{(\alpha,s)} = \frac{1}{6}\left(\hat{I} + s\hat{\sigma}_\alpha\right)$$

Condition $\hat{\rho}^{(\alpha,s)} \geq 0 \Rightarrow t \geq \log 3$

Total disentanglement for $t \geq t_0 \log 3$

Markovian disentanglment of a particle

$\hat{\rho}(0)$ is arbitrary

free particle in frictionless bath $\dfrac{d\hat{\rho}}{dt} = -i\left[\dfrac{\hat{p}^2}{2m}, \hat{\rho}\right] - \dfrac{D}{2}\left[\hat{x}, \left[\hat{x}, \hat{\rho}\right]\right]; \quad t \geq 0$

$t_0 = \sqrt{m/D}$ = decoherence time

One expects that $\hat{\rho}(t)$ gets disentangled for $t \gtrsim t_0$.

Proof: • $W(x,p;t) \geq 0$ if $t > 3^{1/4} t_0$

$\Downarrow$

• $P(x,p;t) \geq 0$ if $t > 1.9\cancel{7} t_0$

$\Downarrow$

• $\mathcal{M}(t): \hat{\rho}(0) \to \hat{\rho}(t)$ disentangles

D. 1987
Halliwell, Zoupas 1995
Kiefer & D. 2001

Khalfin & Tsirelson 1992