Title: PSI 2018/2019 - Explorations in Quantum Information - Lecture 2

Speakers: Eduardo Martin-Martinez

Collection: PSI 2018/2019 - Explorations in Quantum Information (Martin-Martinez)

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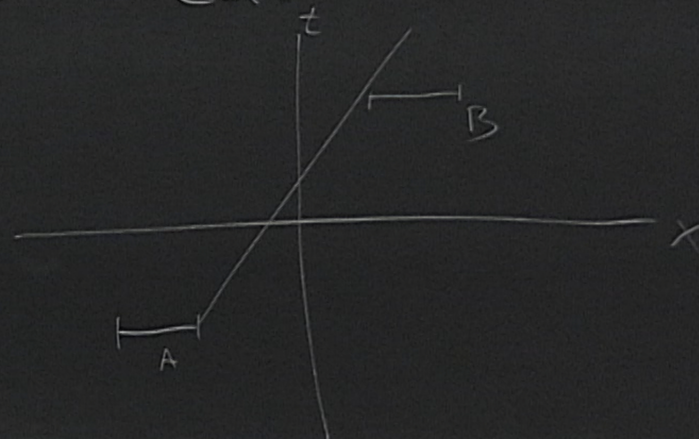
URL: http://pirsa.org/19040052

R. D Sorkin arXiv: gr-qc 9302018 (1993)
F. Dowker arXiv: 1111.2308 (2011)
D.M.T Benincasa et al. CQG 31, 075007 (2014)



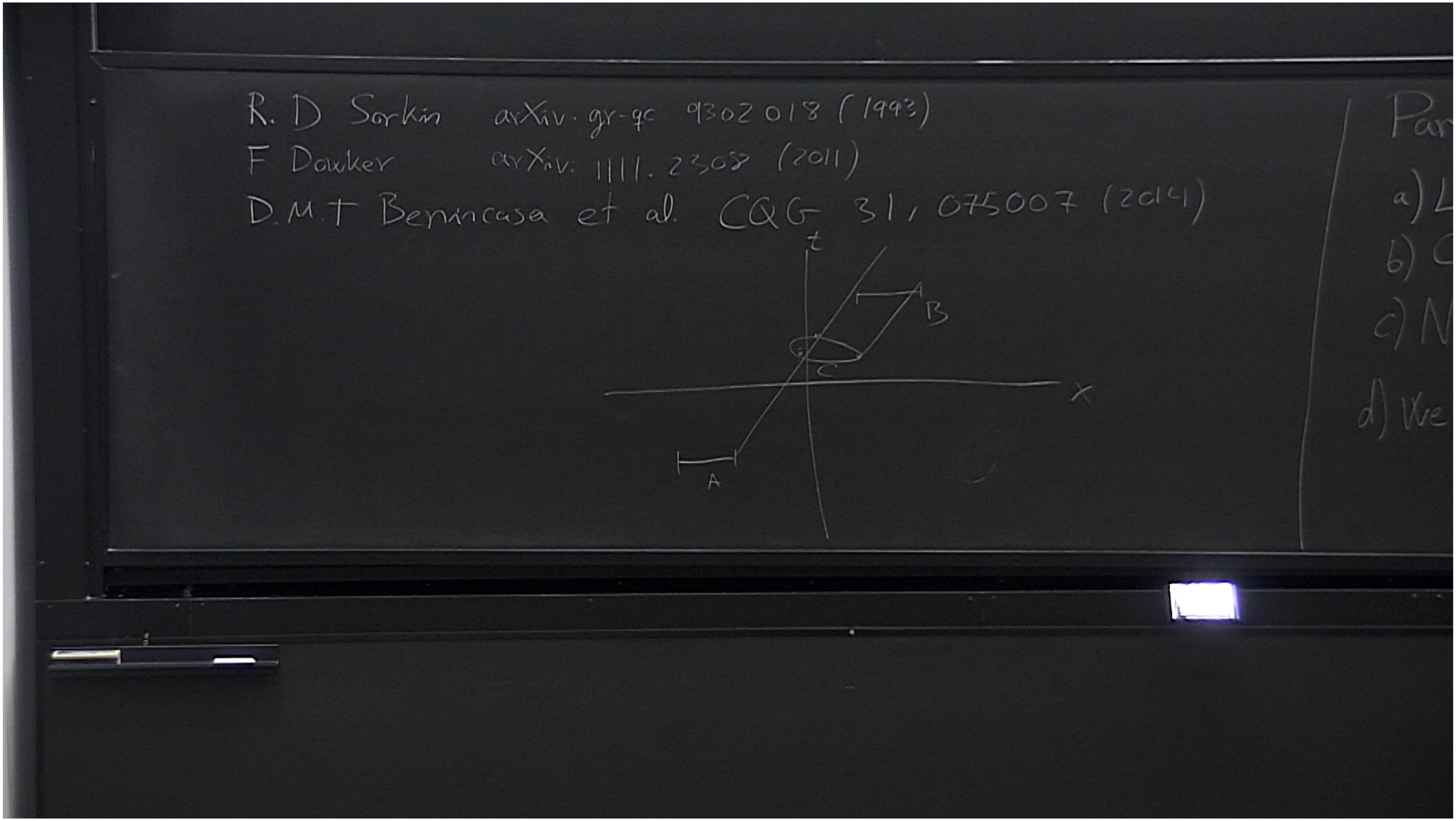
07 (2014)

x

Particle detectors:

a) Localized quantum systems
b) Couple to quantum fields
c) Non-relativistic (in their internal energy levels)

d) We can measure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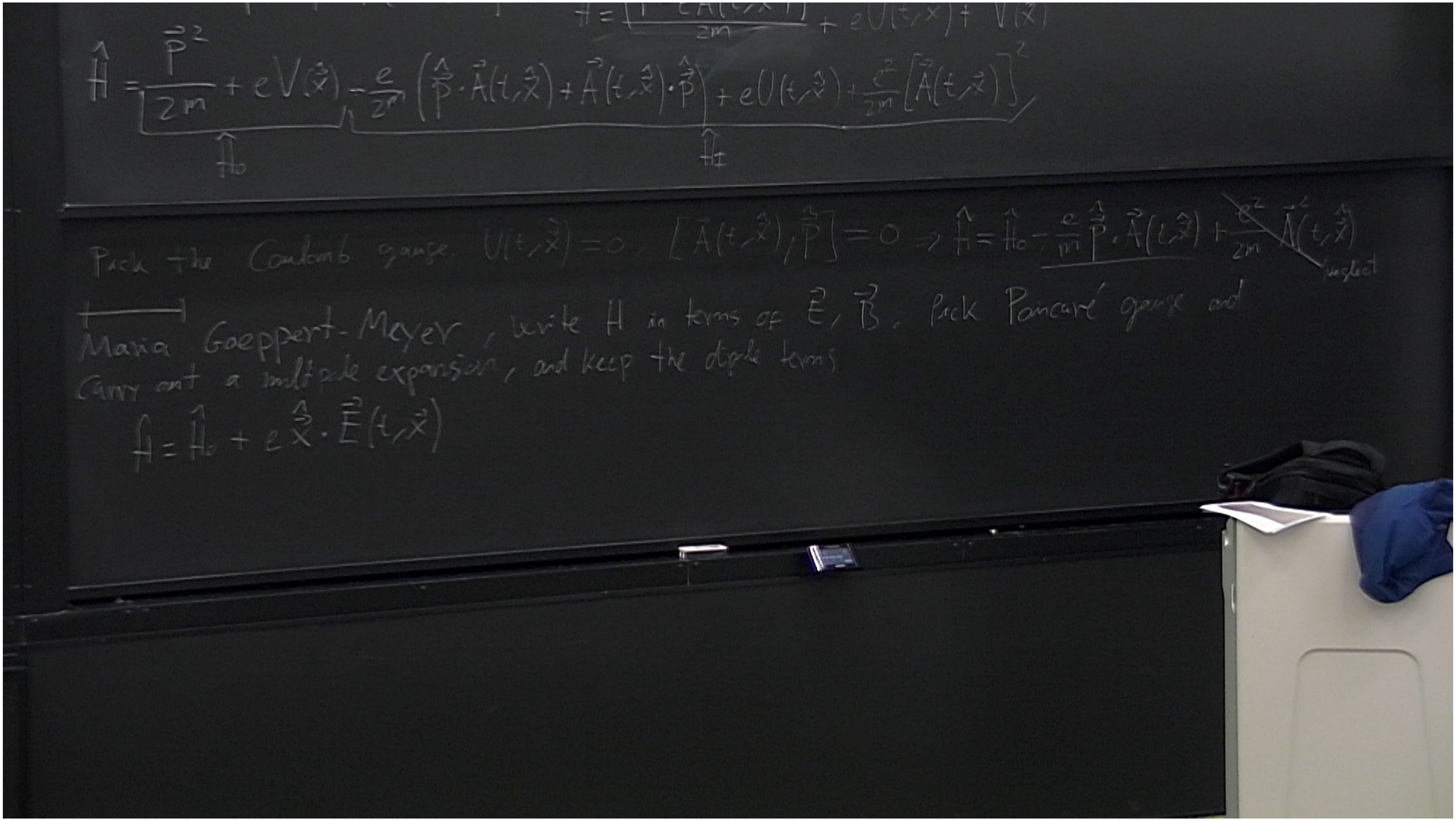
t
B
C
x
A

the light-matter interaction from first principles

An electron in a Hydrogen-like atom: $\hat{H} = \frac{\hat{\vec{P}}^2}{2m} + e\,V(\hat{\vec{x}})$ (orbitals, etc)

electron couples to the EM field. $\hat{H} = \frac{\left(\hat{\vec{P}} - e\hat{\vec{A}}(t,\hat{\vec{x}})\right)^2}{2m} + eU(t,\hat{\vec{x}}) + V(\hat{\vec{x}})$

$$\hat{H} = \underbrace{\frac{\vec{P}^2}{2m} + eV(\hat{\vec{x}})}_{\hat{H}_0} \underbrace{- \frac{e}{2m}\left(\hat{\vec{P}}\cdot\vec{A}(t,\hat{\vec{x}}) + \vec{A}(t,\hat{\vec{x}})\cdot\hat{\vec{P}}\right) + eU(t,\hat{\vec{x}}) + \frac{e^2}{2m}\left[\vec{A}(t,\vec{x})\right]^2}_{\hat{H}_I}$$



$\hat H = \frac{[\hat{\vec p} - e\vec A(t,\hat{\vec x})]^2}{2m} + eU(t,\hat{\vec x}) + V(\hat{\vec x})$
$\hat H = \underbrace{\frac{\hat{\vec p}^2}{2m} + eV(\hat{\vec x})}_{\hat H_0} \underbrace{- \frac{e}{2m}\left(\hat{\vec p}\cdot\vec A(t,\hat{\vec x}) + \vec A(t,\hat{\vec x})\cdot\hat{\vec p}\right) + eU(t,\hat{\vec x}) + \frac{e^2}{2m}[\vec A(t,\hat{\vec x})]^2}_{\hat H_I}$
Pick the Coulomb gauge. $U(t,\hat{\vec x}) = 0$, $[\vec A(t,\hat{\vec x}), \hat{\vec p}] = 0 \Rightarrow \hat H = \hat H_0 - \frac{e}{m}\hat{\vec p}\cdot\vec A(t,\hat{\vec x}) + \cancel{\frac{e^2}{2m}\vec A^2(t,\hat{\vec x})}$ neglect
Maria Goeppert-Meyer, write H in terms of $\vec E$, $\vec B$. Pick Poincaré gauge and carry out a multipole expansion, and keep the dipole terms
$\hat H = \hat H_0 + e\hat{\vec x}\cdot\vec E(t,\hat{\vec x})$

A gauge transformation $|\psi\rangle \to e^{ie\chi(t,\vec{x})}|\psi\rangle$

$$\hat{H}_I = e^{i\hat{H}_0 t}\hat{H}_I e^{-i\hat{H}_0 t} = e\hat{\vec{x}}\cdot\vec{E}(\hat{\vec{x}}) = \sum_i\sum_j \langle j|\hat{\vec{x}}\cdot\vec{E}(t,\hat{\vec{x}})|i\rangle e^{i\Omega_{ij}t}|j\rangle\langle i| =$$

$$= e\sum_{i,j}\int d^3x\int d^3x' \underbrace{\langle j|\vec{x}\rangle}_{\psi_j^*(\vec{x})}\underbrace{\langle\vec{x}|\hat{\vec{x}}}_{\vec{x}\underbrace{\langle\vec{x}|\,|\vec{x}'\rangle}_{\delta^{(3)}(\vec{x}-\vec{x}')}}\cdot\underbrace{\vec{E}(t,\hat{\vec{x}})|\vec{x}'\rangle}_{\vec{E}(t,\vec{x}')}\underbrace{\langle\vec{x}'|i\rangle}_{\psi_i(\vec{x}')} e^{i\Omega_{ij}t}|j\rangle\langle i|$$

$$= e\sum_{i\neq j}\int d^3x\, \psi_j^*(x)\,\vec{x}\,\psi_i(\vec{x})\cdot\vec{E}(t,\vec{x})\,e^{i\Omega_{ij}t}|j\rangle\langle i|$$

$g \not\rightarrow g$

$\Delta n = \pm 1$

$\Delta l = \pm 1, 0$

Restricting to two levels:

$i = g, e$
$j = g, e$

$\hat{\sigma}^{+2} = \hat{\sigma}^{-2} = 0$

$|e\rangle\langle g| = \hat{\sigma}^{+}$

$|g\rangle\langle e| = \hat{\sigma}^{-}$

$$H_I = e\int dx\, \underbrace{\left(\vec{F}(\vec{x})\, e^{i\Omega t}\hat{\sigma}^{+} + \vec{F}^{*}(\vec{x})\, e^{-i\Omega t}\hat{\sigma}^{-}\right)}_{\hat{d}(t,\vec{x})} \cdot \vec{E}(t,\vec{x})$$

$$\boxed{\hat{H} = e\int d^3x\; \hat{d}(t,\vec{x}) \cdot \hat{\vec{E}}(t,\vec{x})}$$

$$\vec{F}(\vec{x}) = \psi_e(\vec{x})\,\vec{x}\,\psi_g^{*}(\vec{x})$$

Smearing vector

F

a)

b)

c)

d) W