# Photo-detection in Lindblad

## Dictionary from photons to dot observables

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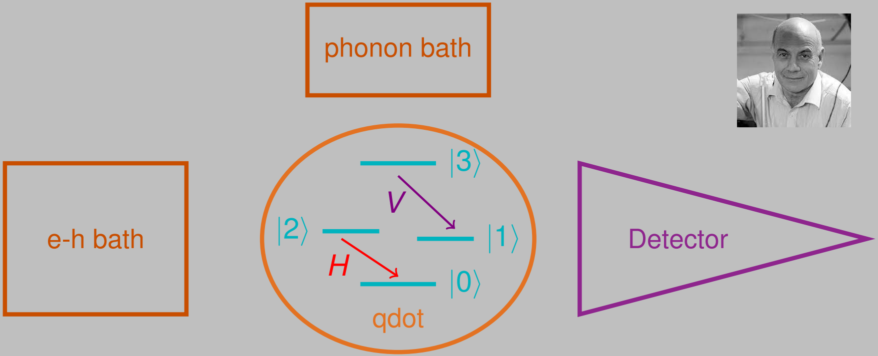
# Light emission from a quantum dot

## Light: A proxy for measurement of quantum dot




Measure: Photon Color and Polarization

Simulate: Lindblad for the dot

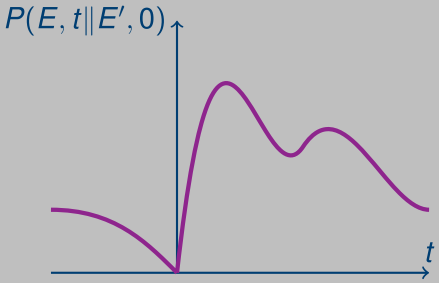
# Conditional photo-events

Photon events: $E = \big(\text{Color, Polarization}\big)$

- Conditional probability

$$P(E, t|E', 0)$$

- Preparation: $E'$ (if $t > 0$)
- Measurement: $E$




Standard problem in Lindblad theory

Rediscovering forgotten insights?

# Non-standard setting in open systems

## Bath NOT measured

$$\begin{tikzcd}
|\Psi_{t=0}\rangle_{dot+rad} \arrow[r, "e^{-iHt}"] \arrow[d, "Tr_{rad}(\rho)"'] & |\Psi_t\rangle_{dot+rad} \arrow[d, "Tr_{rad}(\rho)"] \\
\rho_{dot}(t=0) \arrow[r, "e^{tL}"] & \rho_{dot}(t)
\end{tikzcd}$$

Photo-detection: A measurement of the bath

- How does the dot know about the measurement?
- Dictionary: Photon-observables $\mapsto$ qdot-observables

# Unitary evolution: Conceptual simplicity

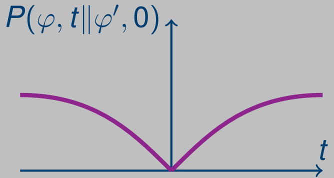
## Computational nightmare

**Measurement=Preparation**

A measurement does not reveal $|\psi\rangle$,
it determines a new $|\psi\rangle$

**Born rule:**

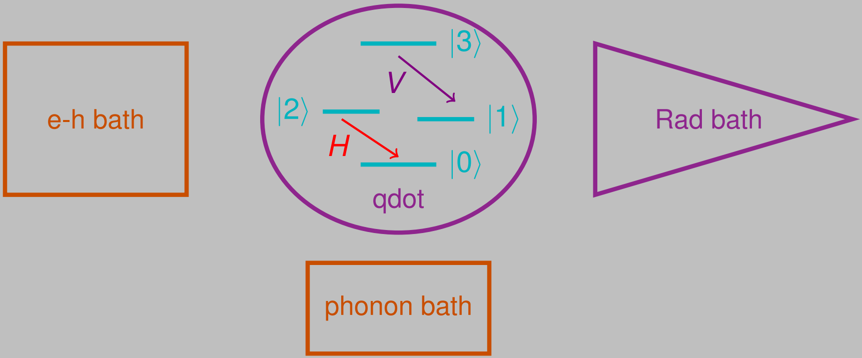
$$Prob(\varphi, t|\varphi', 0) = |\langle\varphi|\, e^{-iH|t|}\, |\varphi'\rangle\,|^2$$




$\varphi$ and $\varphi'$: States after the measurement

# Lindblad evolutions: Computational simplicity

## Conceptually confusing




**Lindblad: Finite dimensional (Markovian) model**

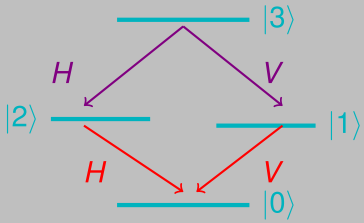
- $\dim \mathcal{H}_{\text{dot}} =$ Finite, e.g. 4
- $\dim \mathcal{H}_{\text{radiation}} = \dim \mathcal{H}_{\text{ e-h bath}} = \dim \mathcal{H}_{\text{phonons}} = \infty$

# Preparation and detection

## Translating bath to system observables

Detecting H prepares $|2\rangle$

Detecting V prepares $|0\rangle$




**Born rule does not work**

$$P(V\varphi, t|H, 0) \neq |\langle 0| e^{tL} |2\rangle|^2$$

**A rule that works**

$$P(V\varphi, t|H, 0) \propto |\langle 1| e^{tL} |2\rangle|^2$$

WHY THIS RULE?

# Dictionary: Photon detection $\mapsto$ qdot observables

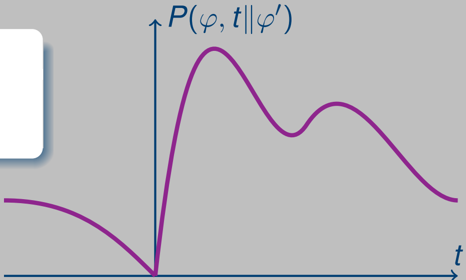
Photonic state: $\varphi$, Qdot state $\psi$

First photo-detection prepares the dot at $|\psi'\rangle$:

$$P(\varphi, t|\varphi', 0) = Tr\left(E_\varphi e^{tL}\left(|\psi'\rangle\langle\psi'|\right)\right)$$

How to pick $E_\varphi$

- Physical meaning?
- How to find it?



# $E_\varphi$: filling rate of the prepared qdot state

## Rates in Lindblad evolutions

Schrödinger: $$\frac{d\rho}{dt} = L(\rho)$$

$$L(\rho) = -i[H,\rho] + \sum_\alpha \underbrace{D_\alpha}_{jump}(\rho)$$

Heisenberg: $$\frac{dA}{dt} = L^*(A)$$

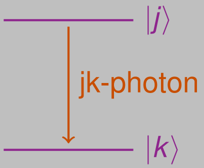
$$L^*(A) = +i[H,A] + \sum_\alpha D^*_\alpha(A)$$

Schrödinger=Heisenberg

$$Tr\left(A\frac{d\rho}{dt}\right) = Tr\Big(AL(\rho)\Big) = Tr\Big(L^*(A)\rho\Big) = Tr\left(\frac{dA}{dt}\rho\right)$$

# Photon current=Rate of prepared dot state

## Conservation of quanta



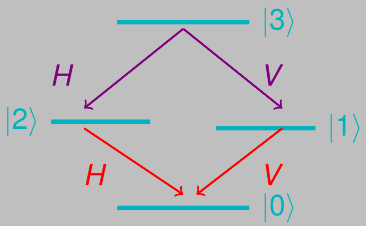

**Dot observable for photo-current**

$$E_{jk} = L^*\Big(\,|k\rangle\langle k|\,\Big) = D^*_{jk}\Big(\,|k\rangle\langle k|\,\Big) = \gamma_{jk}\,|j\rangle\langle j|$$

**Born rule:**

$$P(photocurrent, t|\rho, t=0) = Tr\Big(\underbrace{D^*(\,|k\rangle\langle k|\,)}_{rate}e^{tL}\rho\Big)$$

# Preparation and Detection of polarized light




**Photon preparation and detection: Different recipes**

$$P(V\varphi, t|H, 0) = Tr\Big(D^*(|0\rangle\langle 0|\, e^{tL}\, |2\rangle\langle 2|\,\Big) = \gamma|\,\langle 1|\, e^{tL}\, |2\rangle\,|^2$$