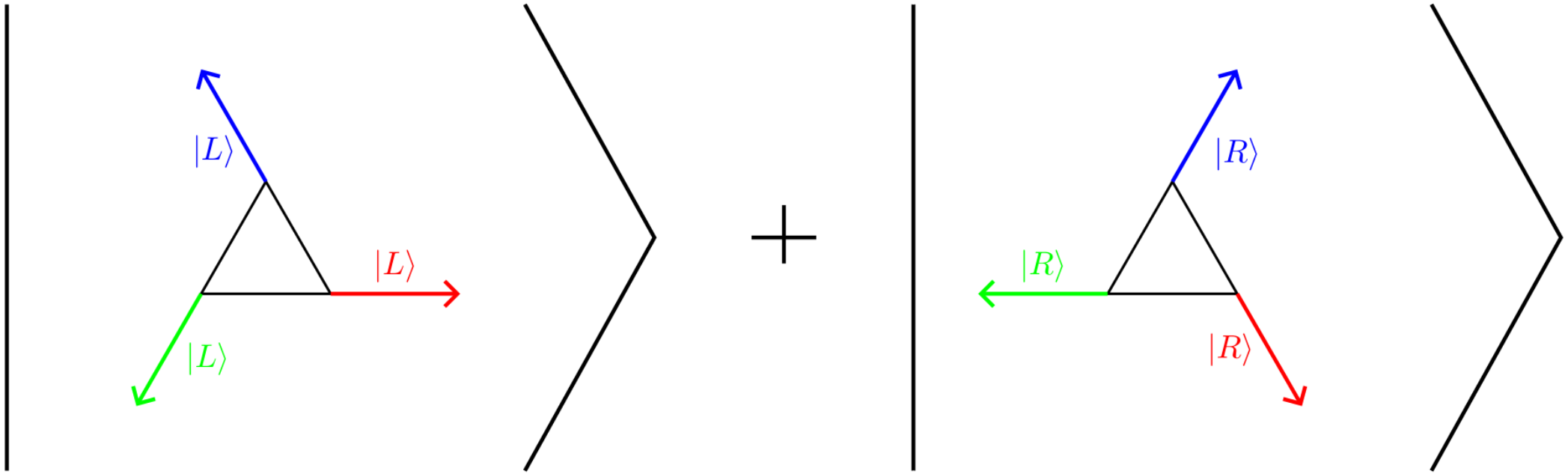

A new potentially integrable source of on-demand path-entangled GHZ photon triplets

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ENTANGLEMENT AND GHZ STATES

- Entanglement is an essential resource in quantum information.
- Efficient on-demand sources of entangled photons are important.
- There is demand for reliable and simple sources of GHZ photon triplets.

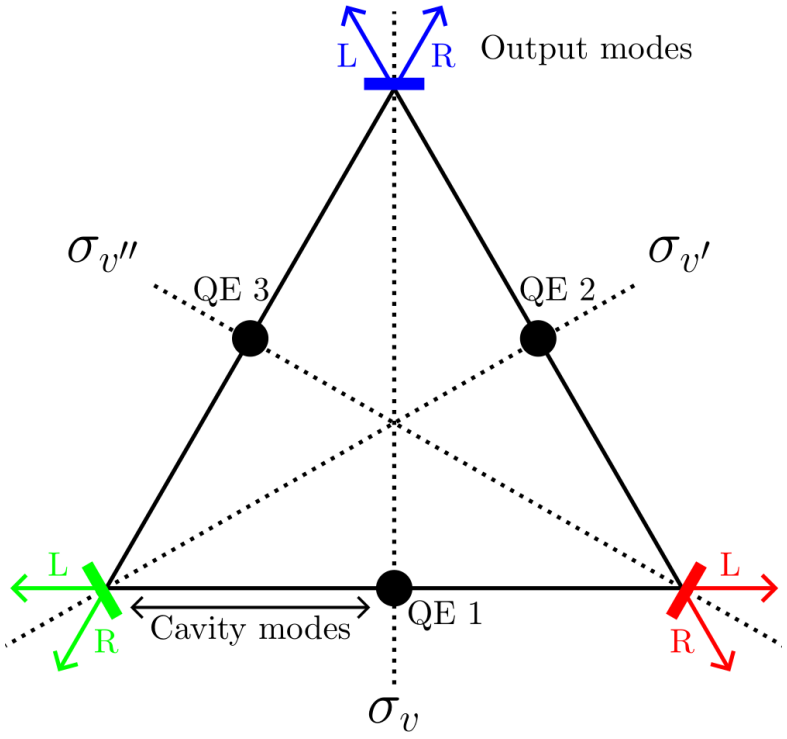
$$\frac{|L, L, L\rangle \pm |R, R, R\rangle}{\sqrt{2}}$$

|L>, |R>: Polarization or path alternatives.

STRONGLY COUPLED C_{3v} SOURCE

- 3 strongly coupled identical quantum emitters (QE)
- Cavity supporting 2 counter propagating modes.
- Light modes and QEs are coupled by a dipole interaction.
- Hamiltonian spectrum is analyzed in terms of a single parameter: Ratio of detuning to coupling

$$\delta/g$$



$$\hat{H}_{QE} = \hbar\nu \sum_{i=1,2,3} \hat{\sigma}_+^{(i)} \hat{\sigma}_-^{(i)} \qquad \hat{H}_F = \hbar\omega \sum_{\mu=1,2} \hat{a}_\mu^\dagger \hat{a}_\mu$$

$$\hat{H}_I = \hbar g \left[\hat{a}_1 \left(\hat{\sigma}_+^{(1)} + \varepsilon \hat{\sigma}_+^{(2)} + \varepsilon^{-1} \hat{\sigma}_+^{(3)} \right) + \text{h.c.} \right.$$
$$\left. - \hat{a}_2 \left(\hat{\sigma}_+^{(1)} + \varepsilon^{-1} \hat{\sigma}_+^{(2)} + \varepsilon \hat{\sigma}_+^{(3)} \right) + \text{h.c.} \right]$$

$$\varepsilon = e^{2\pi i/3}$$

HILBERT SPACE SPLITTING

- Number of quanta is conserved

$$\hat{N}_Q = \underbrace{\sum_{\mu=1,2} \hat{a}_\mu^\dagger \hat{a}_\mu}_{\text{Cavity quanta}} + \underbrace{\sum_{i=1,2,3} \hat{\sigma}_+^{(i)} \hat{\sigma}_-^{(i)}}_{\text{Emitter quanta}}$$

- Hilbert space of strongly coupled system splits into subspaces:

$$\mathcal{H} = \bigoplus_{N_Q} \mathcal{H}_{N_Q}$$

- Symmetry quantum numbers

Rotation gr.		Group C_{3v}		
L	*l*	A_1	A_2	E
	m	1	1	1-2

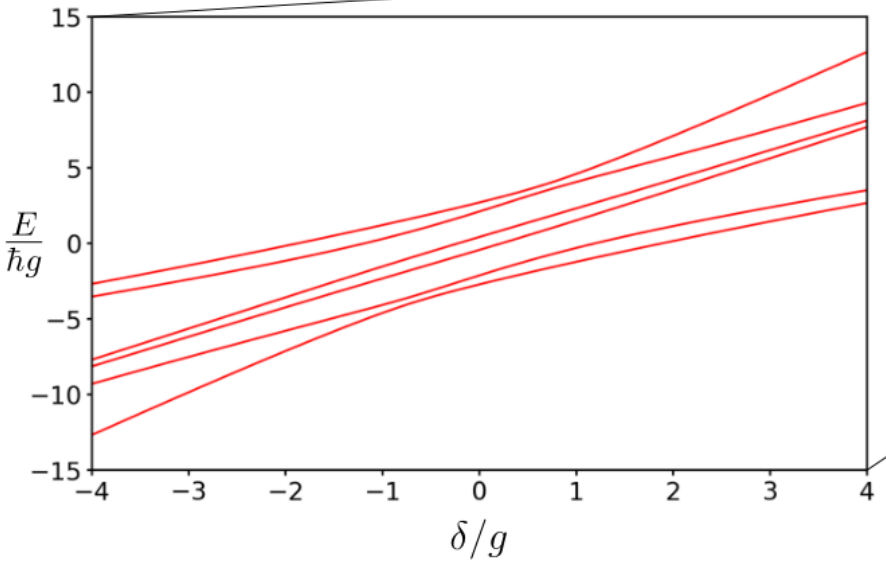
- Further splitting due to symmetry:

$$\mathcal{H} = \mathcal{H}_{A_1} \oplus \mathcal{H}_{A_2} \oplus \mathcal{H}_{E,1} \oplus \mathcal{H}_{E,2}$$

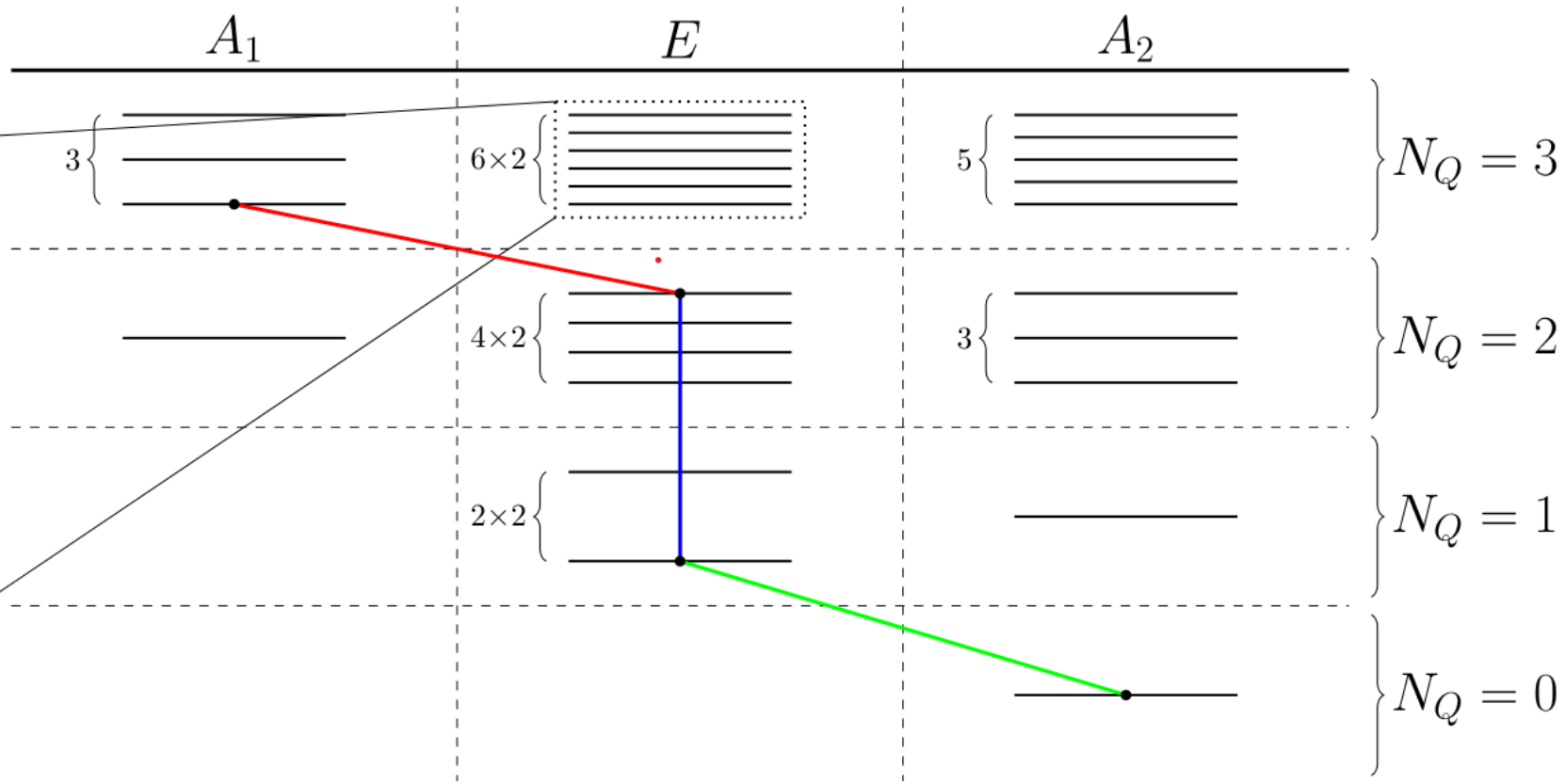
- Dimension of Hilbert subspaces

N_Q	A_1	A_2	E
0	0	1	0×2
1	0	1	2×2
2	1	3	4×2
3	3	5	6×2

Parameter space covered by a single parameter δ/g



Energy levels for N_Q = 3, E subspace



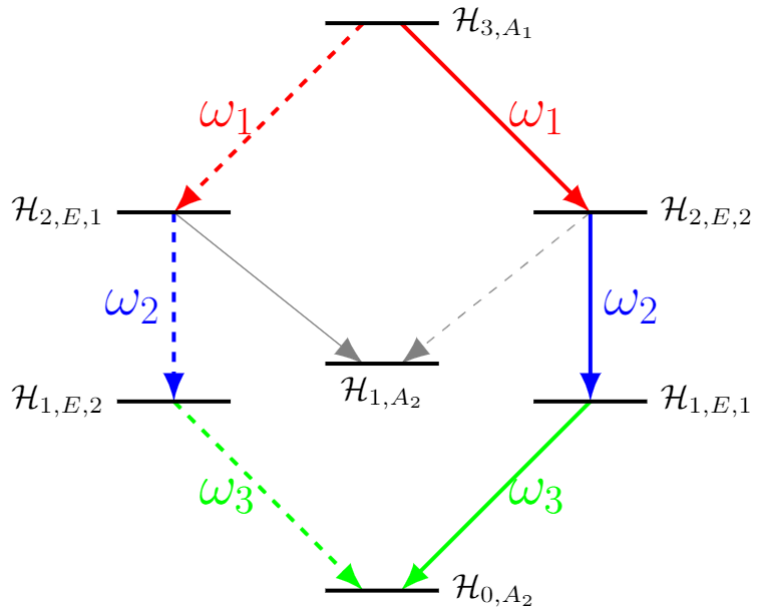
LEVEL MULTIPLETS OF 3 STRONGLY COUPLED QUANTUM EMITTERS IN A C_{3V} SYMMETRIC CAVITY

EMITTED GHZ PHOTON TRIPLET

- By the symmetry-induced selection rules we can see which transitions are allowed.

- Decay through the output mirrors yields *path-entangled* GHZ photon triplets.

$$|\psi_{\text{out}}\rangle = \frac{|L,L,L\rangle \pm |R,R,R\rangle}{\sqrt{2}}$$



- For photons:

$$|E,1\rangle \rightarrow |L\rangle \qquad |E,2\rangle \rightarrow |R\rangle$$

- Product rule:

$$E \times E = A_1 + A_2 + E$$