Superradiance-induced destabilization of the many-body order in strongly correlated light-matter systems

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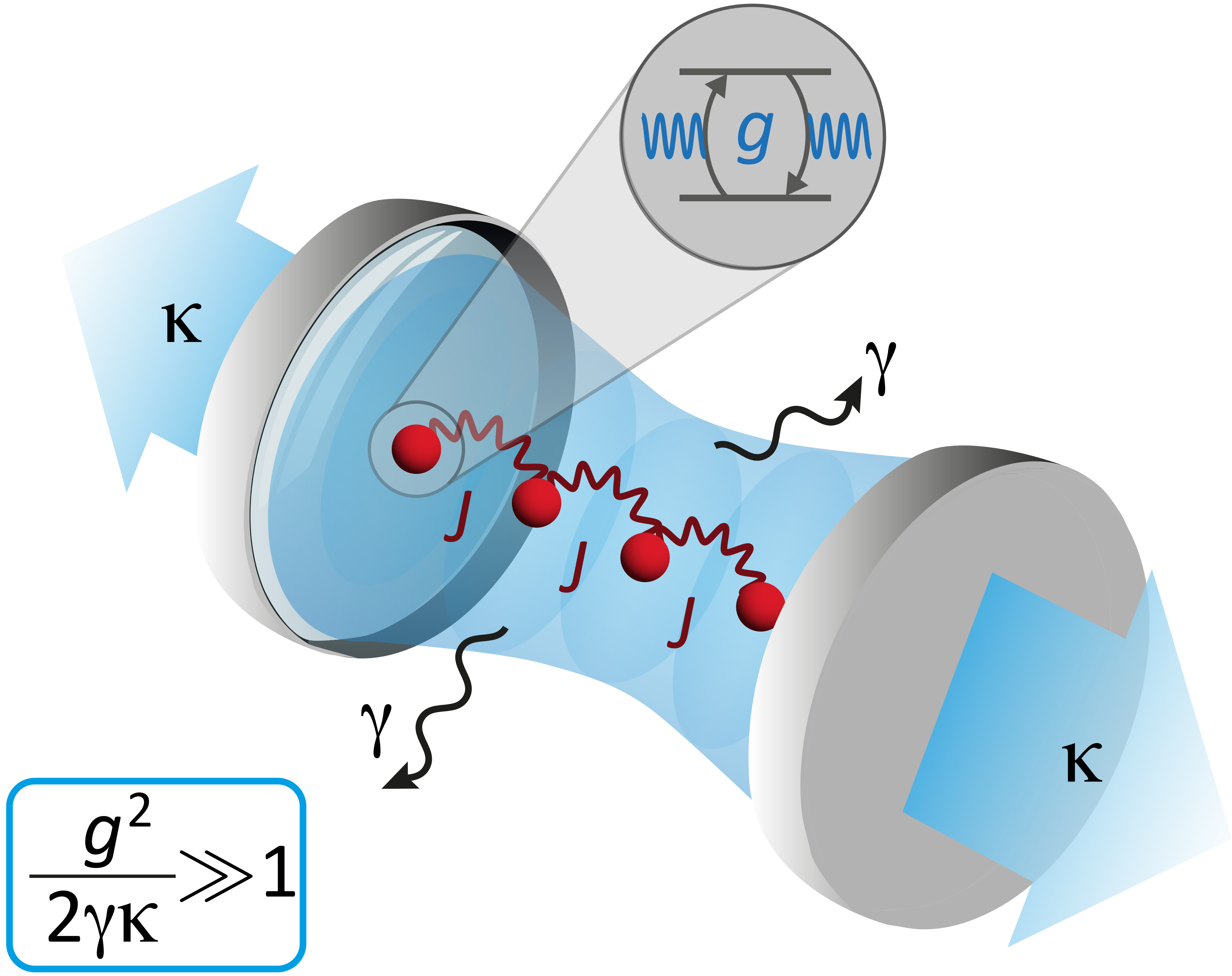
Systems of interest

cQED



$$\boxed{\frac{g^2}{2\gamma\kappa} \gg 1}$$

$$\begin{aligned} H &= H_0^{\text{cavity}} + H_0^{\text{spin}} + H_I^{\text{spin-photon}} + H_I^{\text{spin-spin}} \\ &= \omega\left(a^\dagger a + \frac{1}{2}\right) + \varepsilon \sum_j s_j^z + \frac{2g}{\sqrt{N}}(a^\dagger + a) \sum_j s_j^x \\ &- \sum_{\langle i,j \rangle} (J_x s_i^x s_j^x + J_y s_i^y s_j^y + J_z s_i^z s_j^z) \end{aligned}$$

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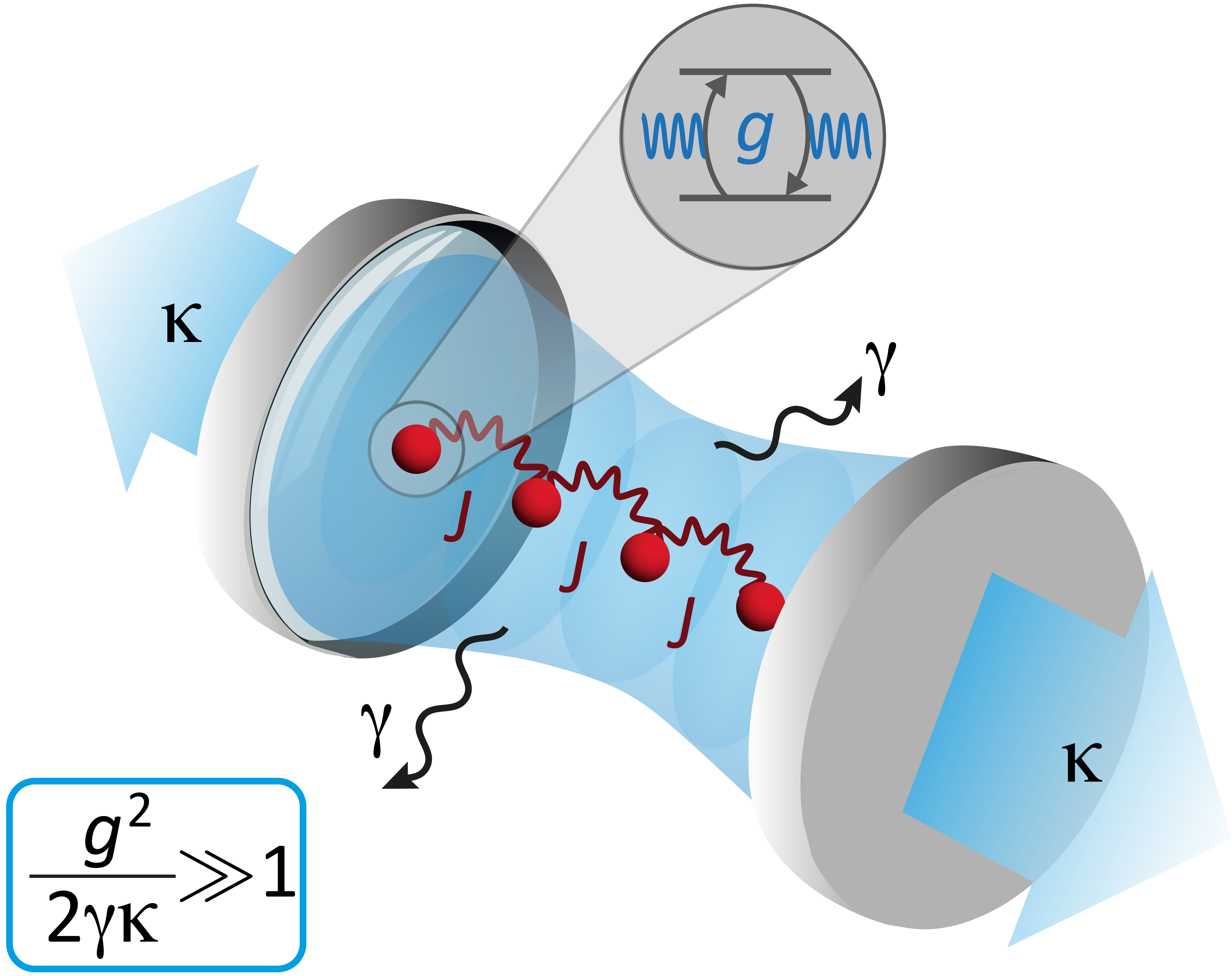

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Dicke model

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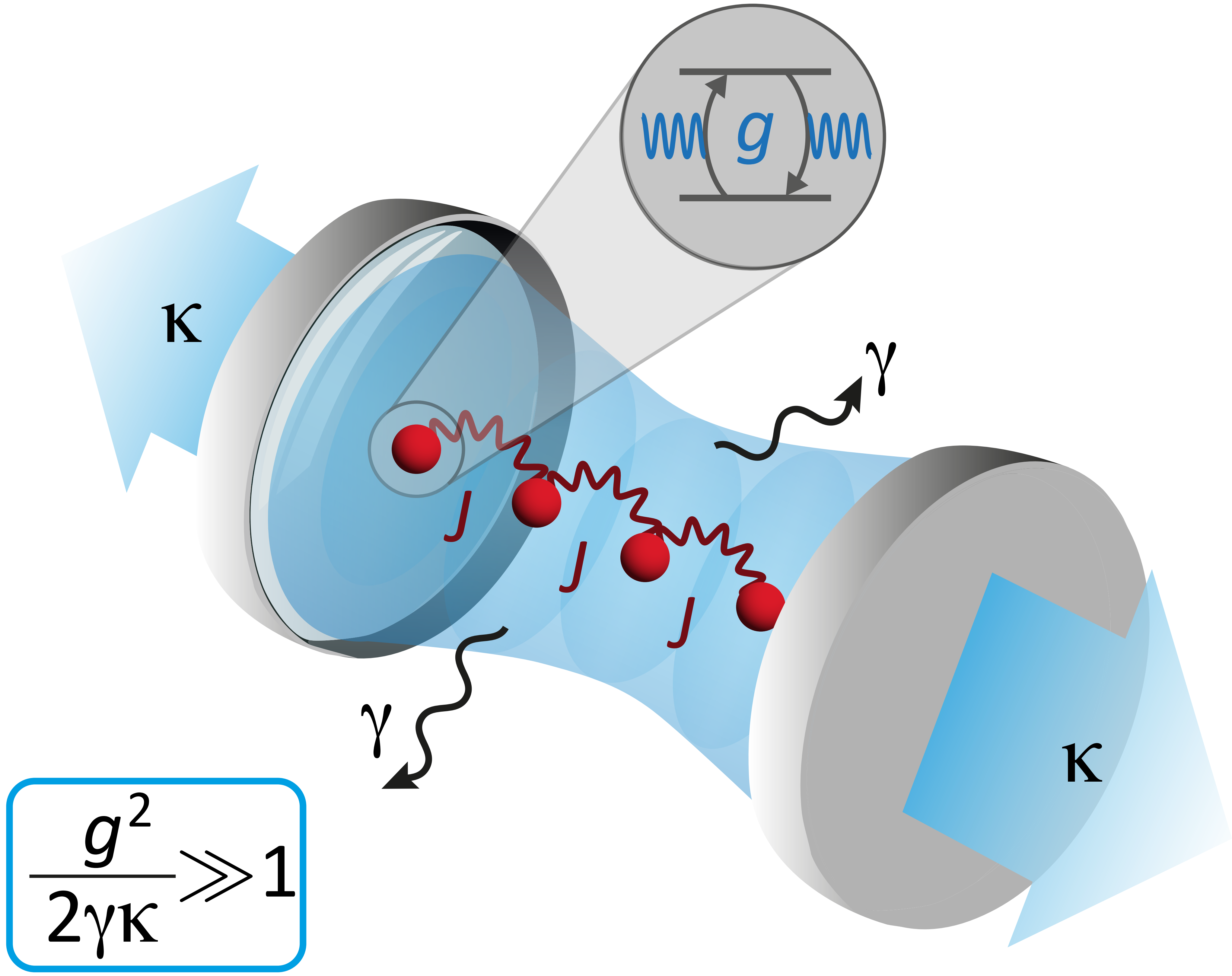

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Dicke model

Heisenberg model

Numerical challenges

Different nature and demand

Electrons/Spins

Photons

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- Highly entangled

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(intuitive) variational approach

NGS-DMRG Method: Variational non-Gaussian approach + DMRG

- **Hybrid non-Gaussian wavefunction ansatz**

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- **Minimization**

$$E\Big(\{\lambda_{\mathbf{q}}\}, \Delta_R, \{\xi_{\mathbf{q}}\}, |\psi_e\rangle\Big) = \big\langle \Psi\big|\mathcal{H}\big|\Psi\big\rangle$$

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- **Flux**

- **Minimization**

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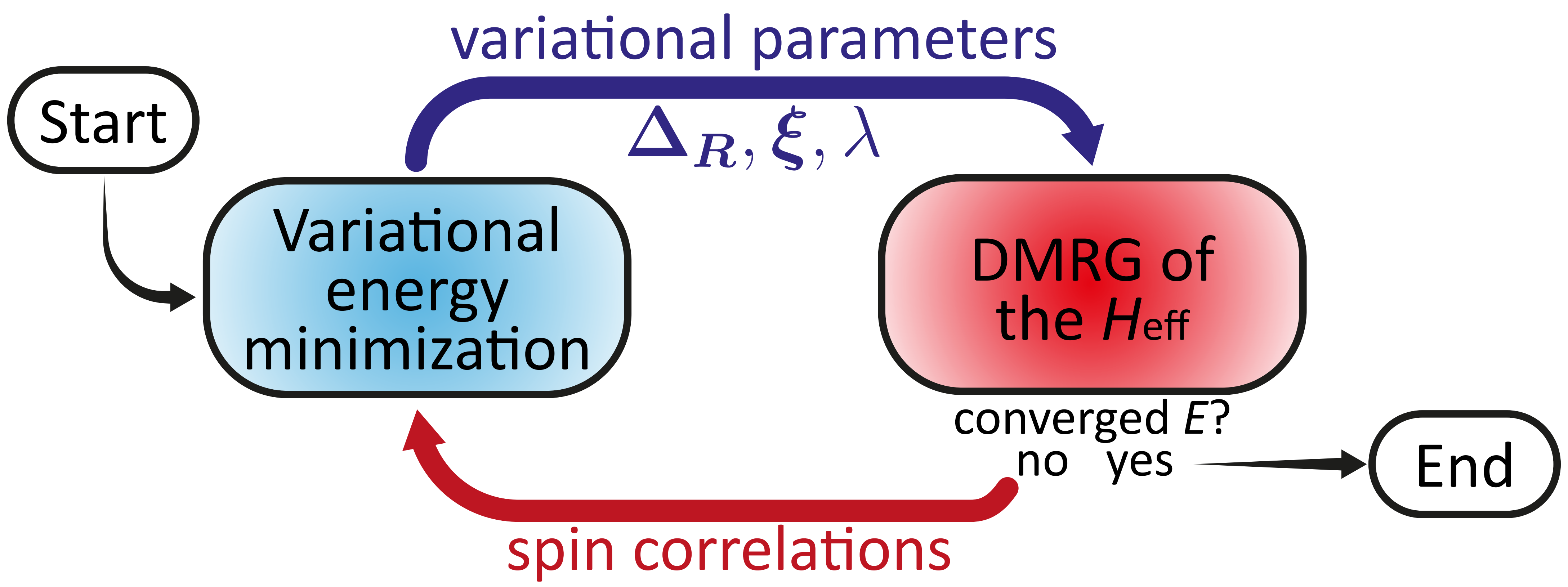
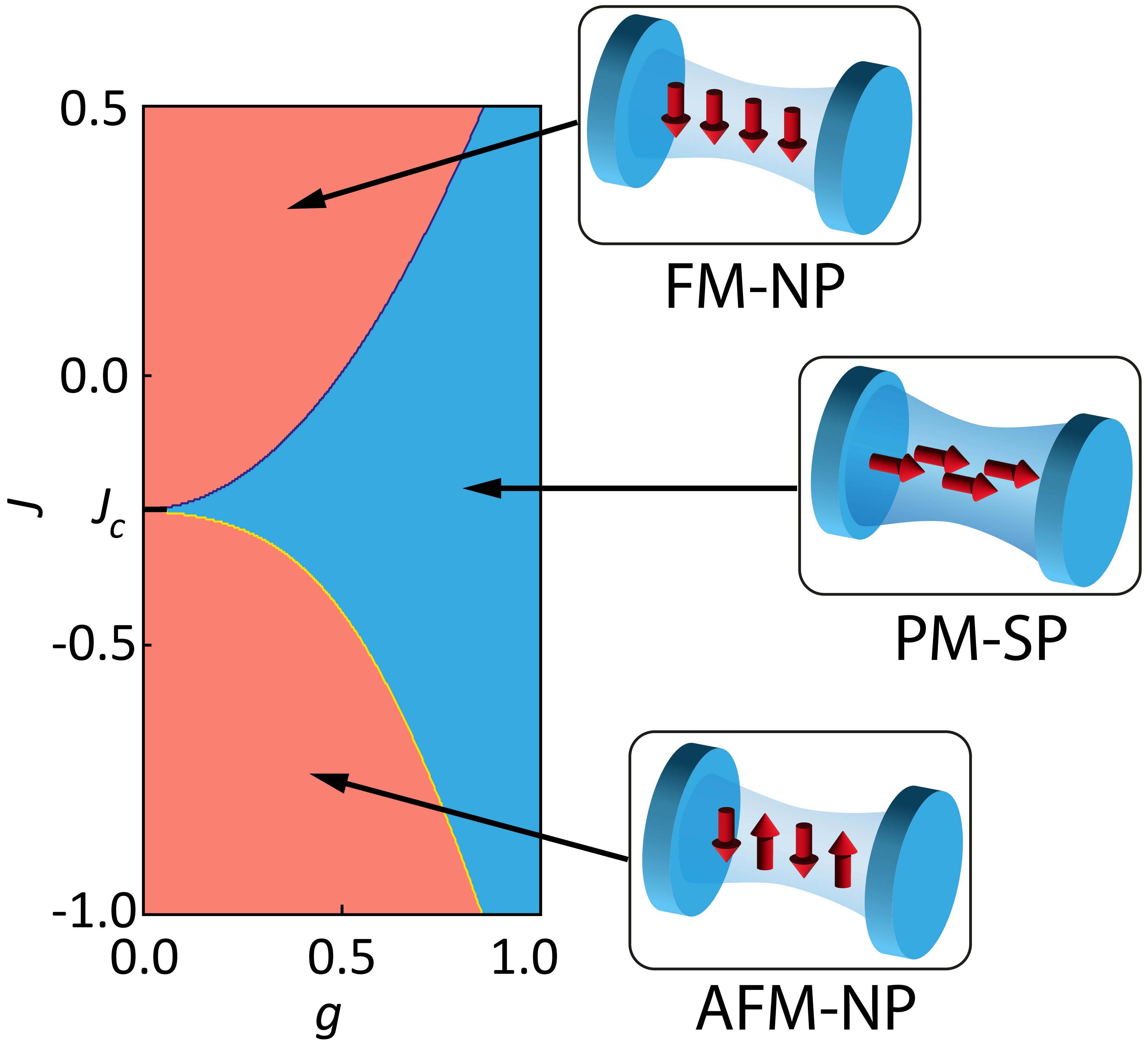


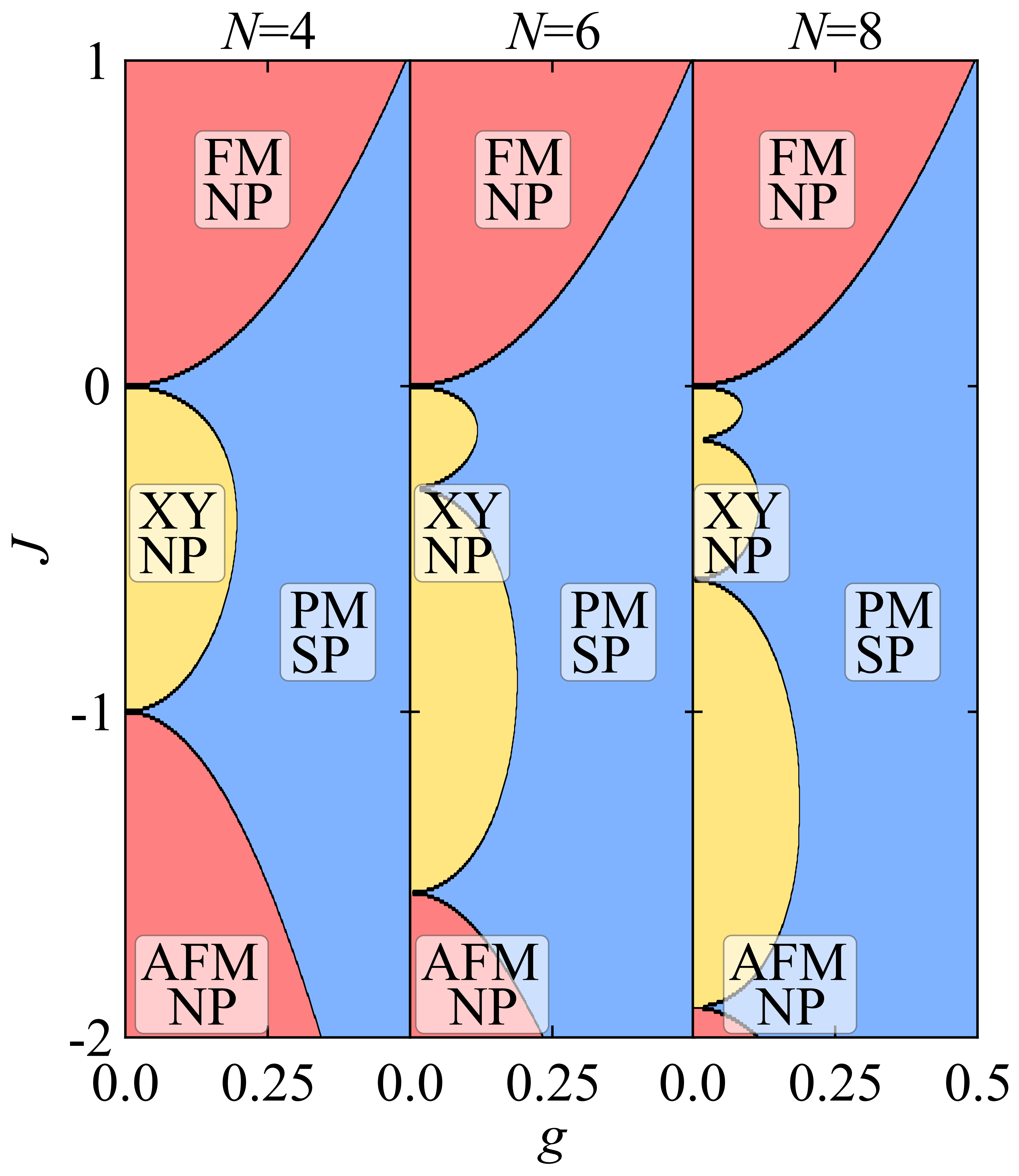
Selected Results

Diagrams of Ising and XXZ interactions

Dicke-Ising model: Rich phase diagram



Dicke-XXZ: XY phase suppresion



Concluding remarks and next steps

- Developed a novel method for studying strongly correlated light-matter systems.
- Revealed rich results with interesting phases and a complex phase diagram.
- Extended the literature by studying a broader class of Dicke-Heisenberg models, beyond Dicke-Ising.
- Study temporal dynamics directly related to quantum batteries.
- Apply the method to other composite systems.
- Investigate frustration in more complex geometries.

Thank you