Peratic Phase Transition by Bulk-to-Surface Response

Phys. Rev. Research **4**, 043009 (2022)

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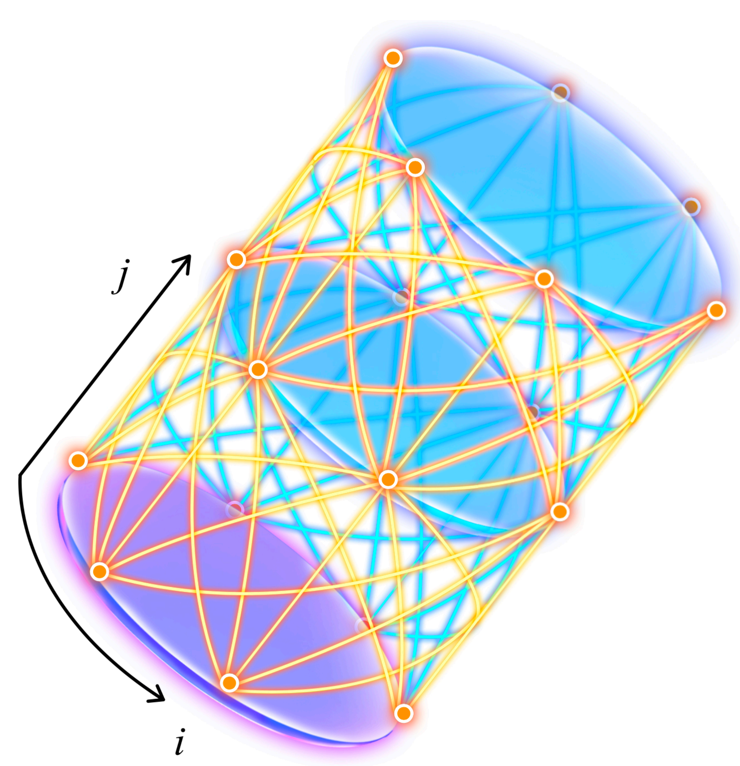
Introduction.—

We establish a duality between many-body dynamics and static Hamiltonian ground states for both classical and quantum systems. We construct **frustration free Hamiltonians** whose ground state phase transitions have rigorous duality to chaotic transitions in dynamical systems. By this duality, we show the corresponding ground state phase transitions are characterized by bulk-to-surface response, which are then dubbed "peratic" meaning defined by response to the boundary. Our prediction of peratic phase transition has direct consequences in **Rydberg atomic arrays**.

Classical Model.— *Emergent chaotic dynamics in a classical Hamiltonian ground state*



- Layer structure
- Local couplings
- Inter-layer couplings only

- Frustration Free Spin Hamiltonian

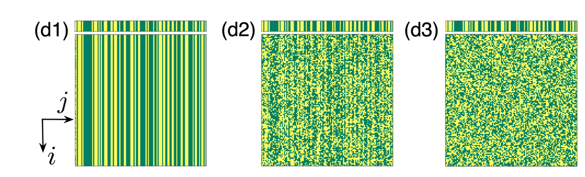
$$H_{\rm bulk} = -\sum_i \sum_{j>0} z_{ij} {\rm sgn}\left(u_j + \sum_{m=-M}^{M} w_m^{[ij]} z_{i+m,j-1} \right),$$

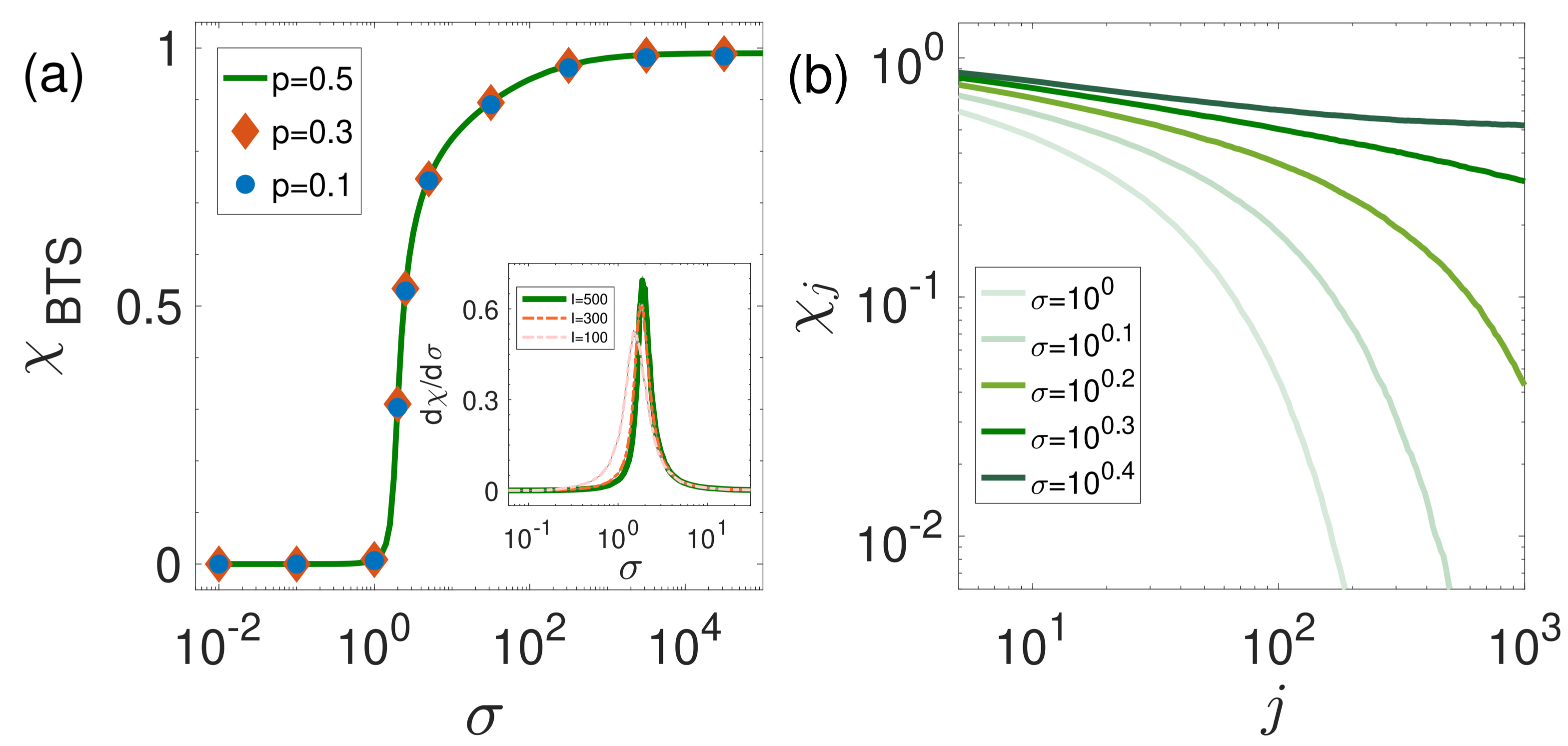
$$H_{\rm surf} = -\sum_i h_{\rm surf}^{[i]} z_{i,0}\,.$$

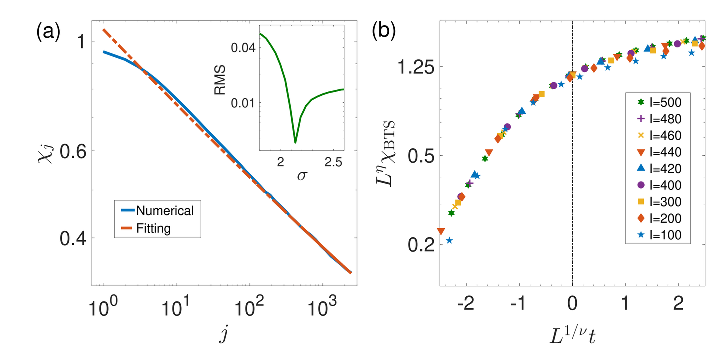
$$z_{i0}^{\rm g} = {\rm sgn}\left(h_{\rm surf}^{[i]}\right),\ z_{i,j>0}^{\rm g} = {\rm sgn}\left(u_j + \sum_{m=-M}^{M} w_m^{[ij]} z_{i+m,j-1}^{\rm g} \right)$$

- Bulk-to-Surface Response

$$\chi_{\rm BTS} = \lim_{h_{\rm surf}\to 0} \left[\frac{1}{IJ} \sum_{ij} {\rm Var}\left(z_{ij}\right)|_{h_{\rm surf}} \right]$$







Finite Size Scaling

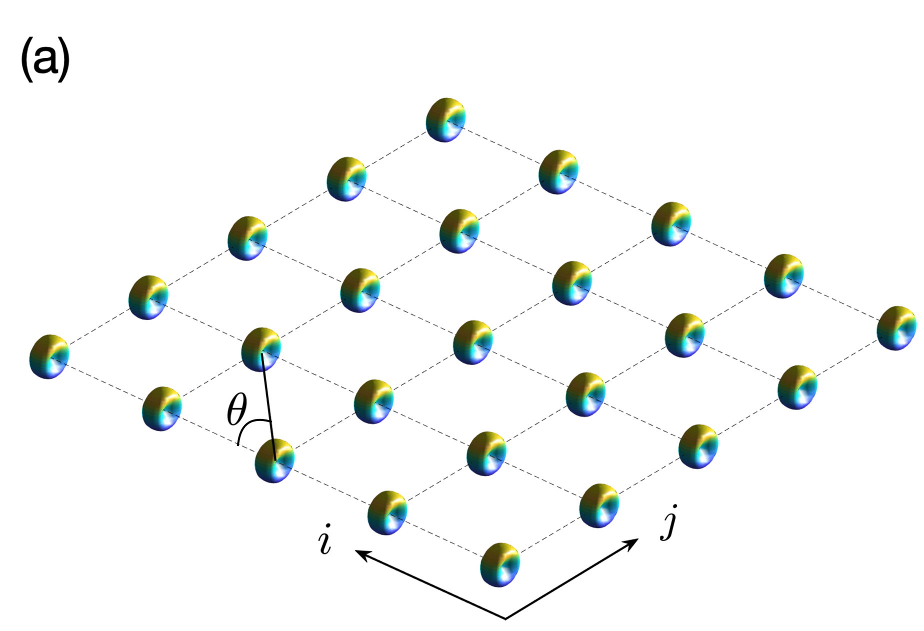
$$\chi_{\rm BTS}(t, L) = L^{-\eta} G(Lt^{\nu})$$

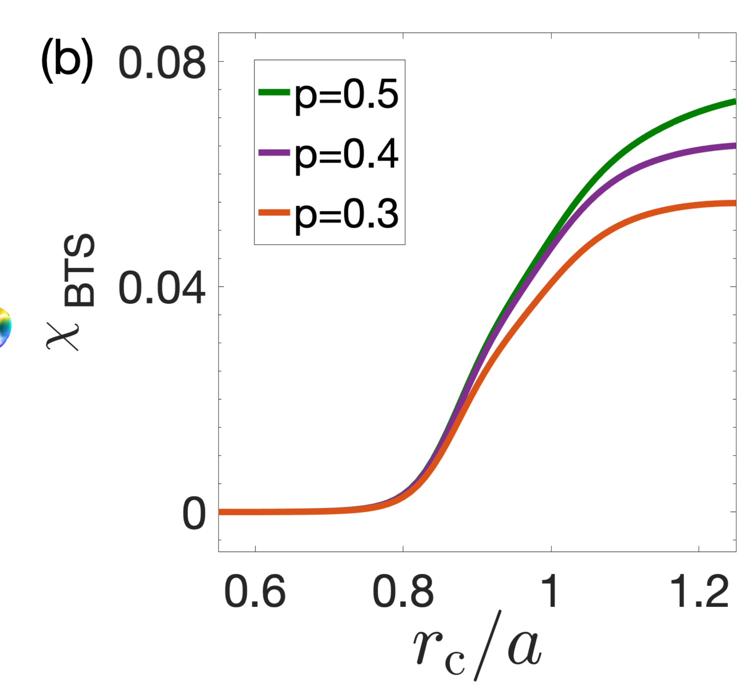
$$\eta = 0.172,\ \nu = 2.73$$

Experimental Candidate.— *Rydberg atomic arrays*

Rydberg p-wave dressing

$$H_1 = \sum_{\mathbf{r},\mathbf{r}'} \frac{V \sin^4 \theta_{\mathbf{r}\mathbf{r}'}}{1 + \left(\frac{|\mathbf{r}-\mathbf{r}'|}{r_c}\right)^6} (\hat{z}_{\mathbf{r}}+1)(\hat{z}_{\mathbf{r}'}+1)/2$$



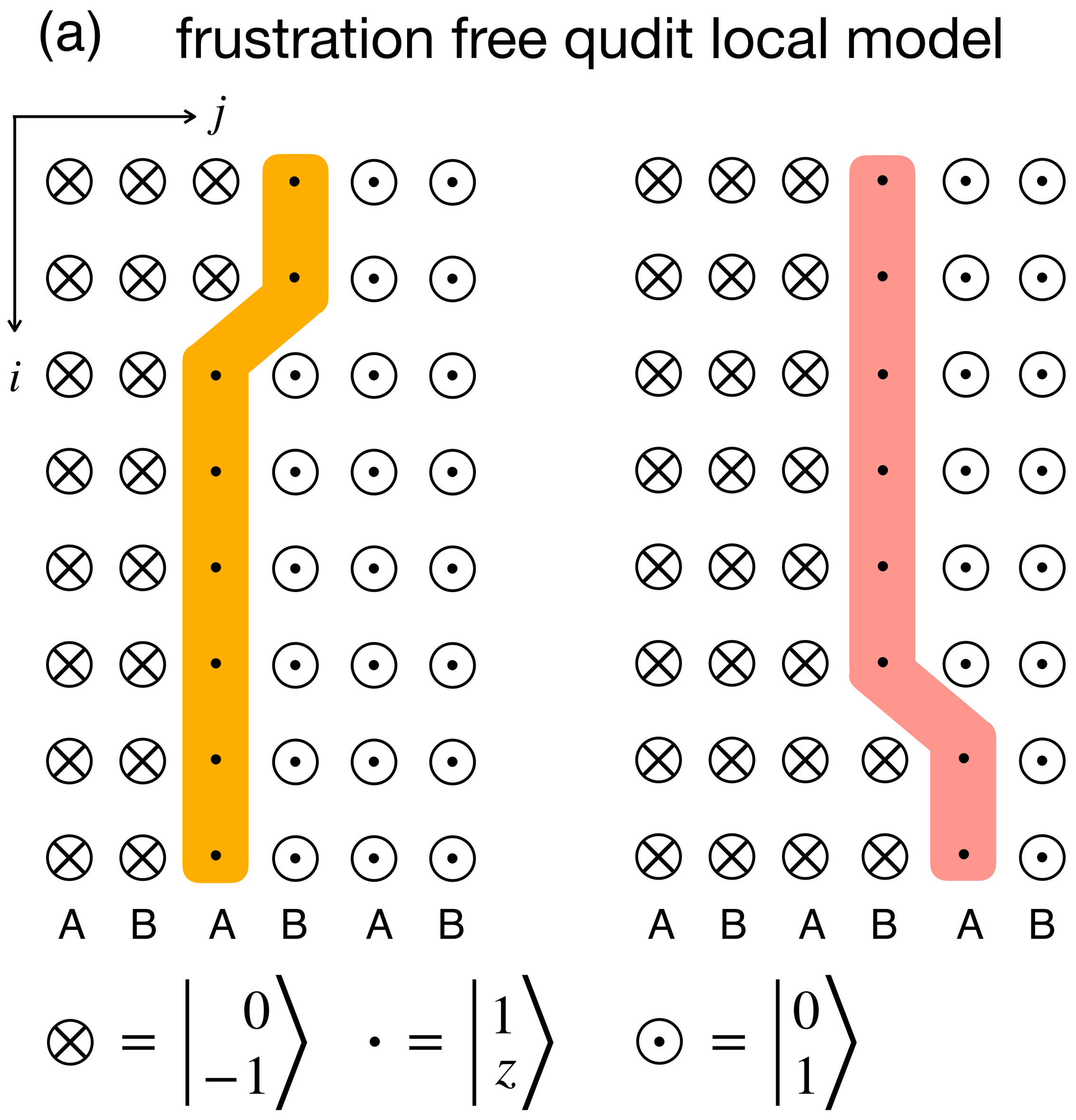


Quantum Model.— *Can we construct a frustration-free model for the quantum peratic phase transition?*

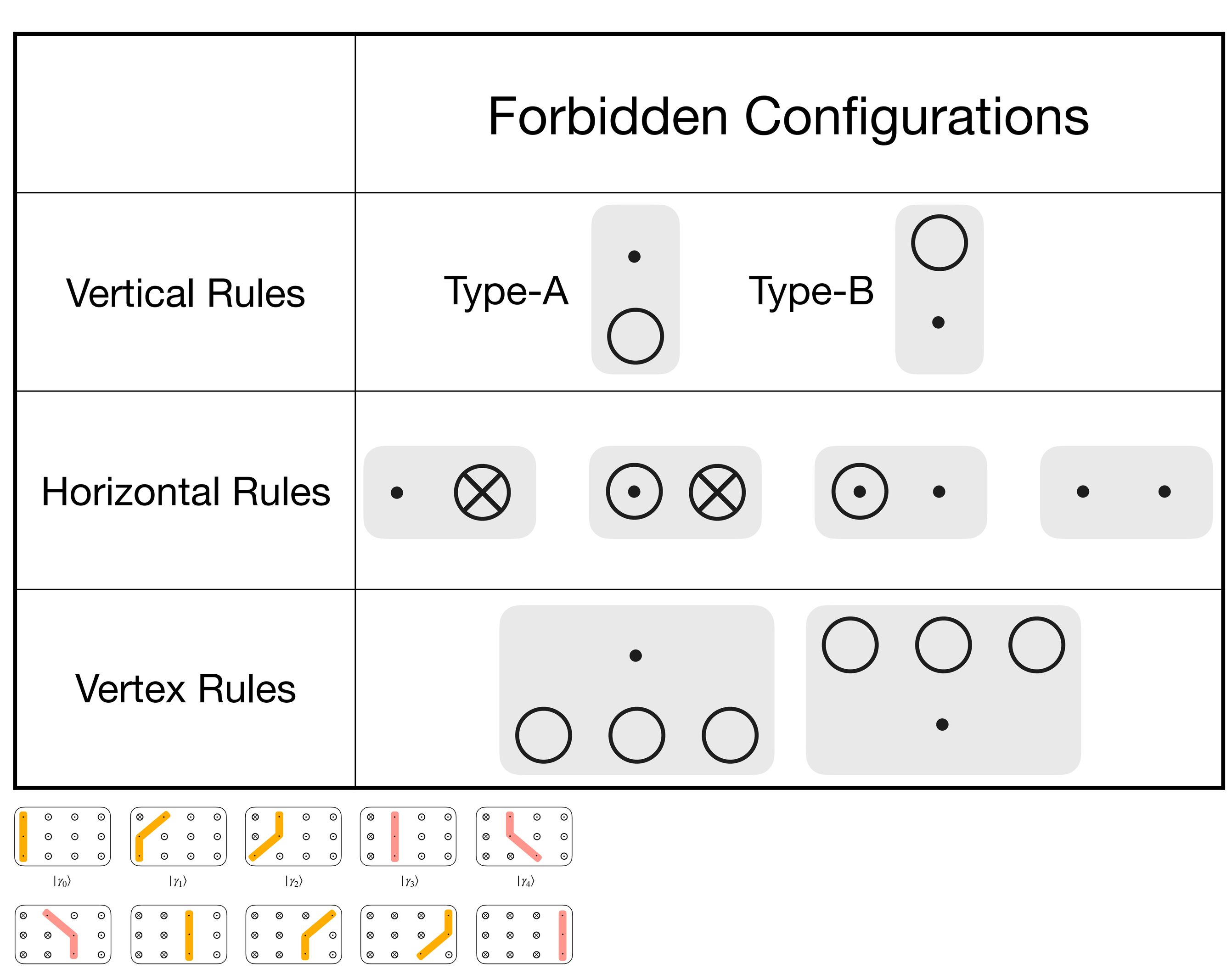
Feynman-Kitaev's Propagating Hamiltonian $H_{\rm prop} = \sum_{j=1}^{L} H_j,\quad H_j = -\frac{1}{2} U_j \otimes |j\rangle\langle j-1| - \frac{1}{2} U_j^\dagger \otimes |j-1\rangle\langle j| + \frac{1}{2} I \otimes (|j\rangle\langle j| + |j-1\rangle\langle j-1|)$

- The history state is the zero energy ground state of a static Hamiltonian $|\eta\rangle = \frac{1}{\sqrt{L+1}} \sum_{j=0}^{L} U_j \cdots U_1 |\psi_0\rangle \otimes |j\rangle$

(a) frustration free qudit local model



(b) local projectors ⇒ low energy subspace



(c) ETH-to-MBL