

QUANTUM INFORMATION MEET GRAVITY

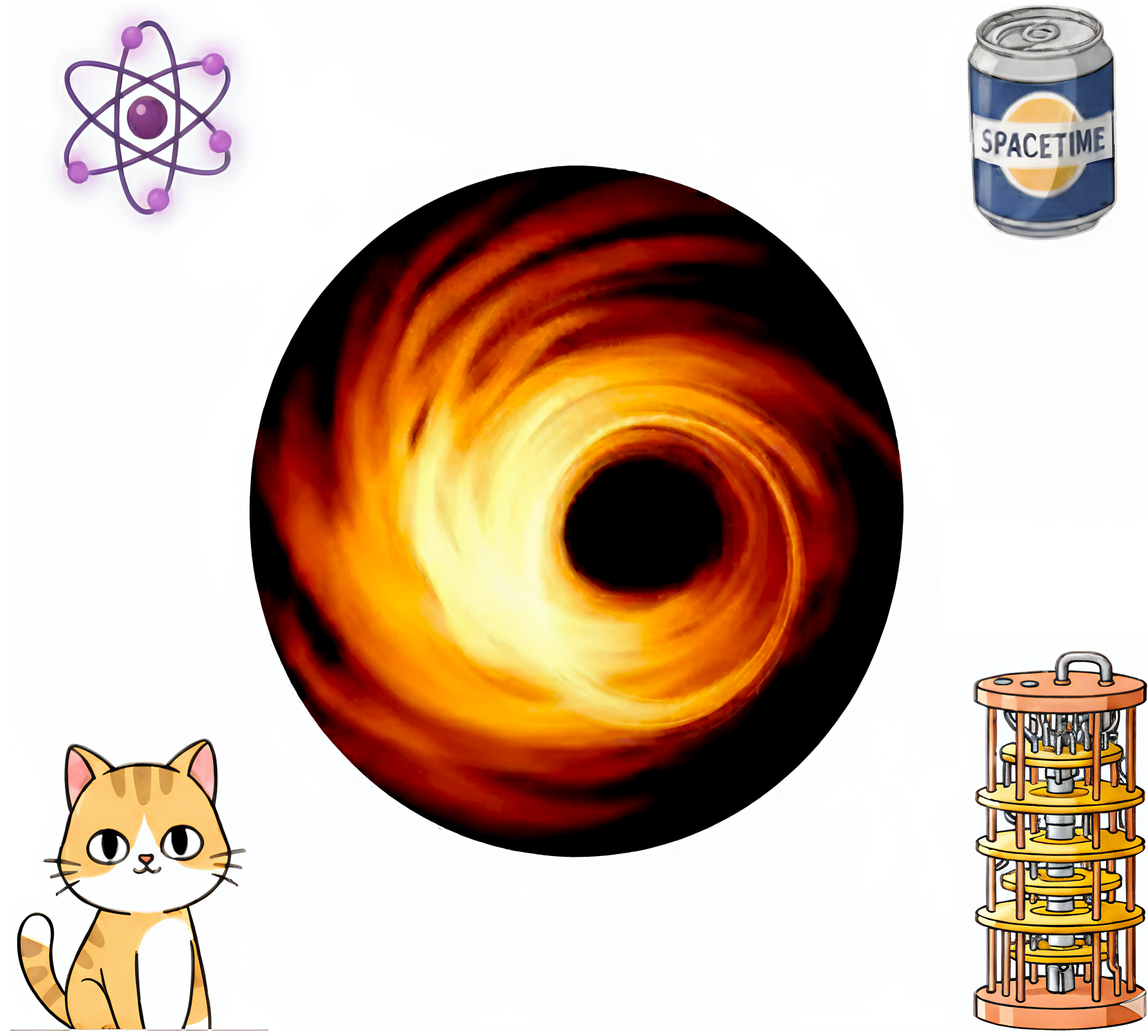
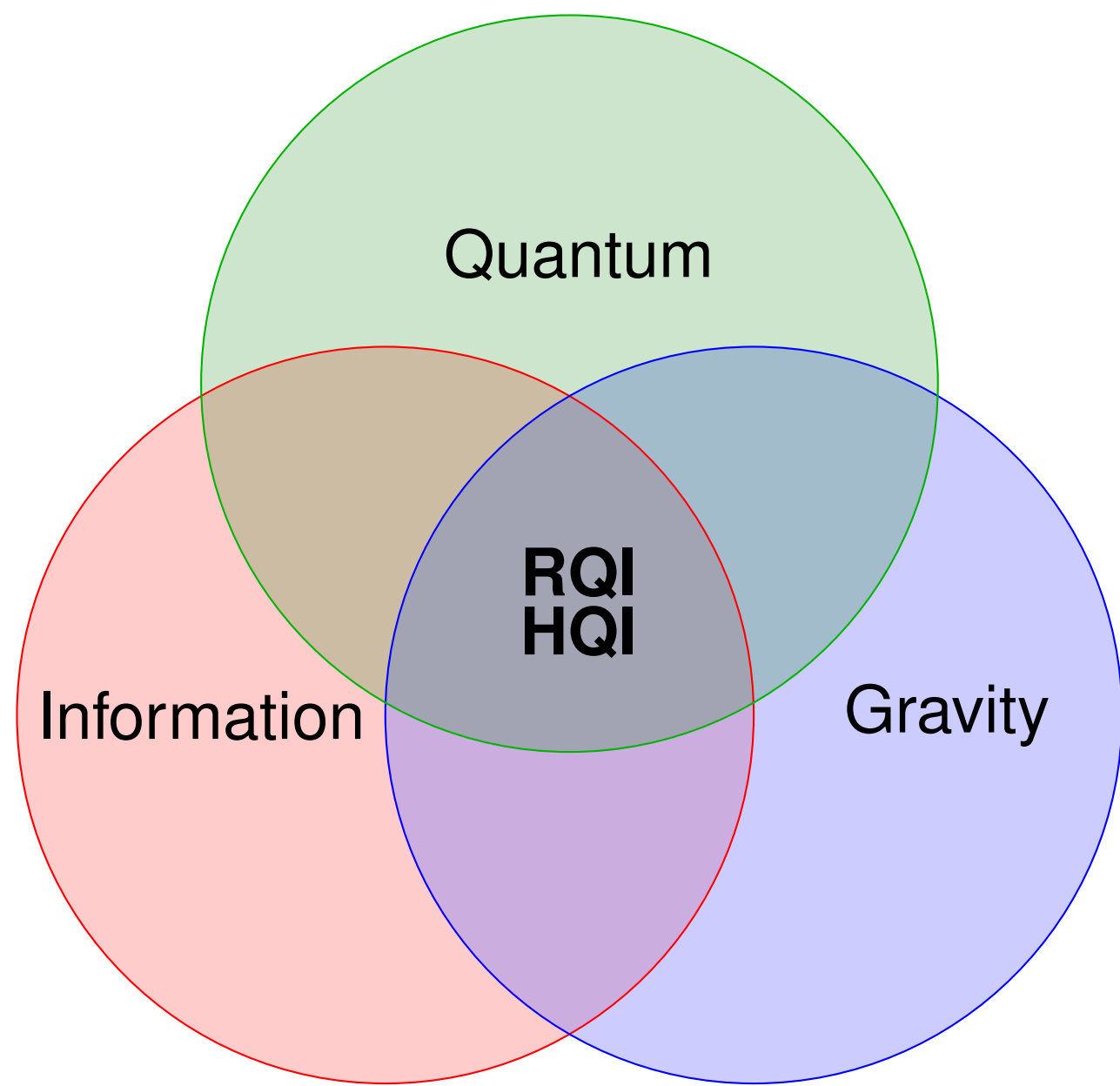
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Background Information

Three major pillars of modern physics.

- **Quantum:** Microscopic and probabilistic physics.
- **Gravity:** Macroscopic physics, curved spacetime.
- **Information:** Quantification and communication.



Magic Harvesting

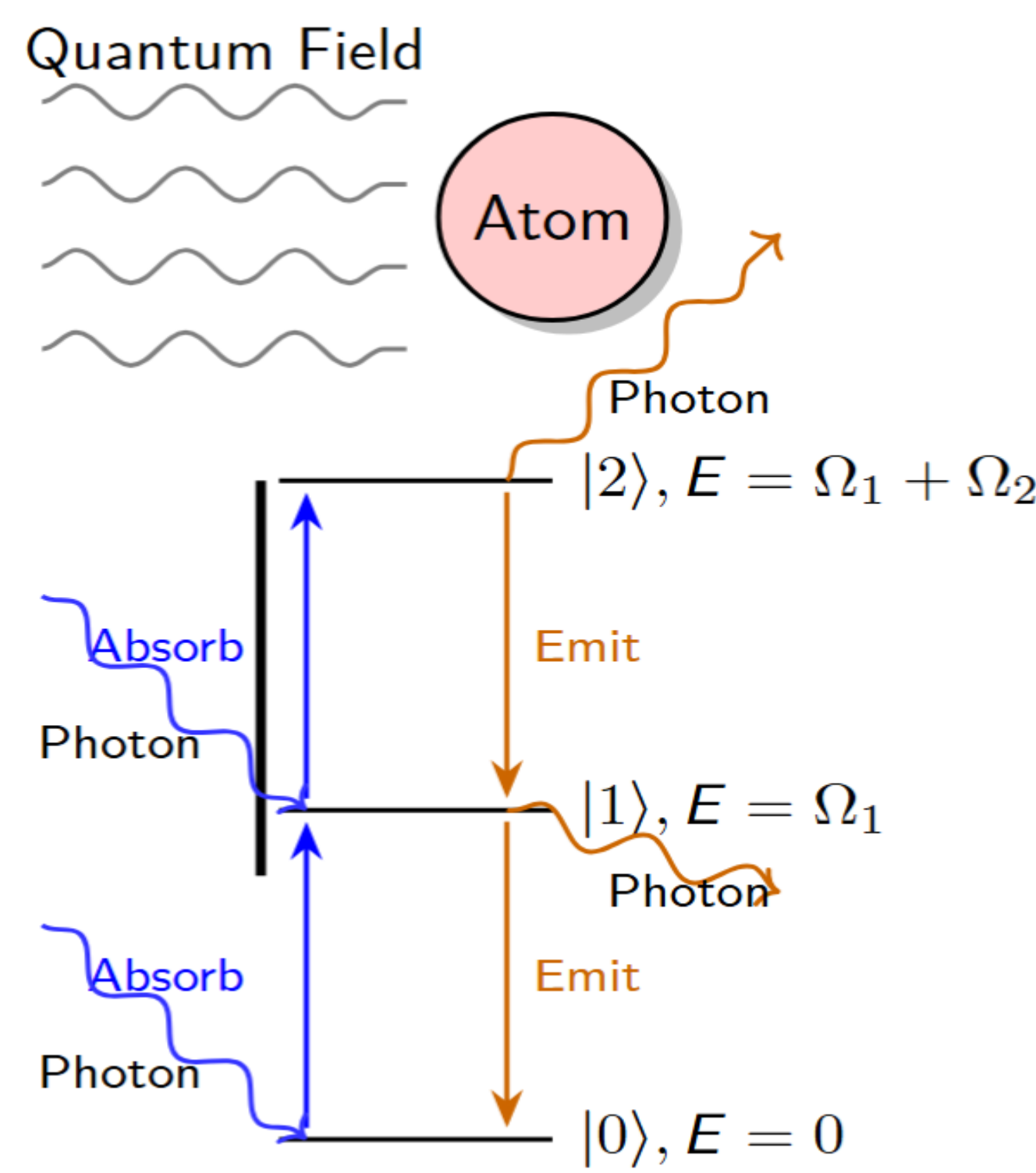


Fig.1: Unruh-DeWitt detector model for qutrit (Lima, Patterson, Tjoo, and Mann 2023).

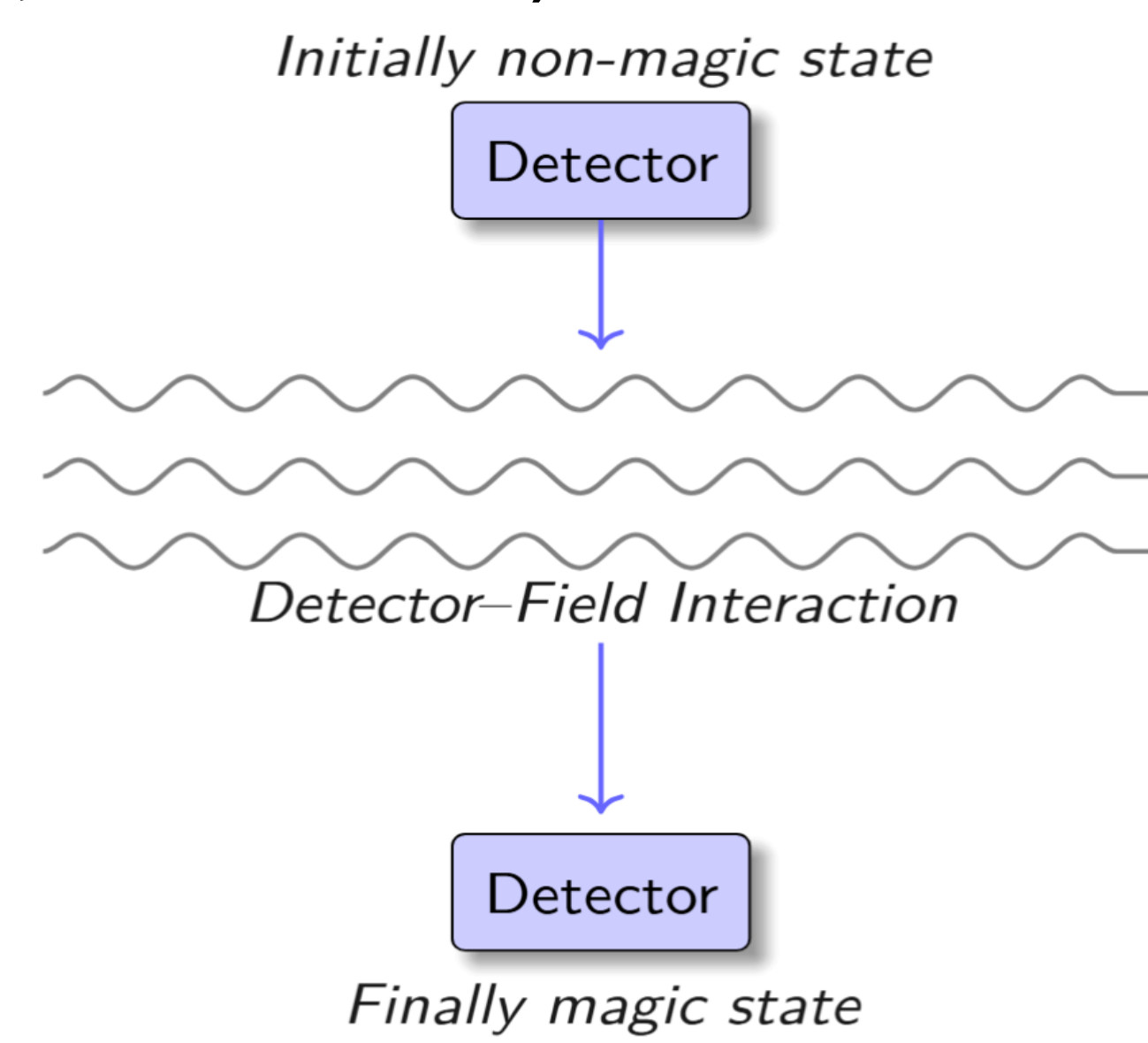


Fig.2: Magic/Mana (Veitch, Mousavian, Gottesman, and Joseph Emerson 2013) Harvesting Protocol (Nyström, Pranzini, and Keski-Vakkuri 2024).

Holographic Complexity

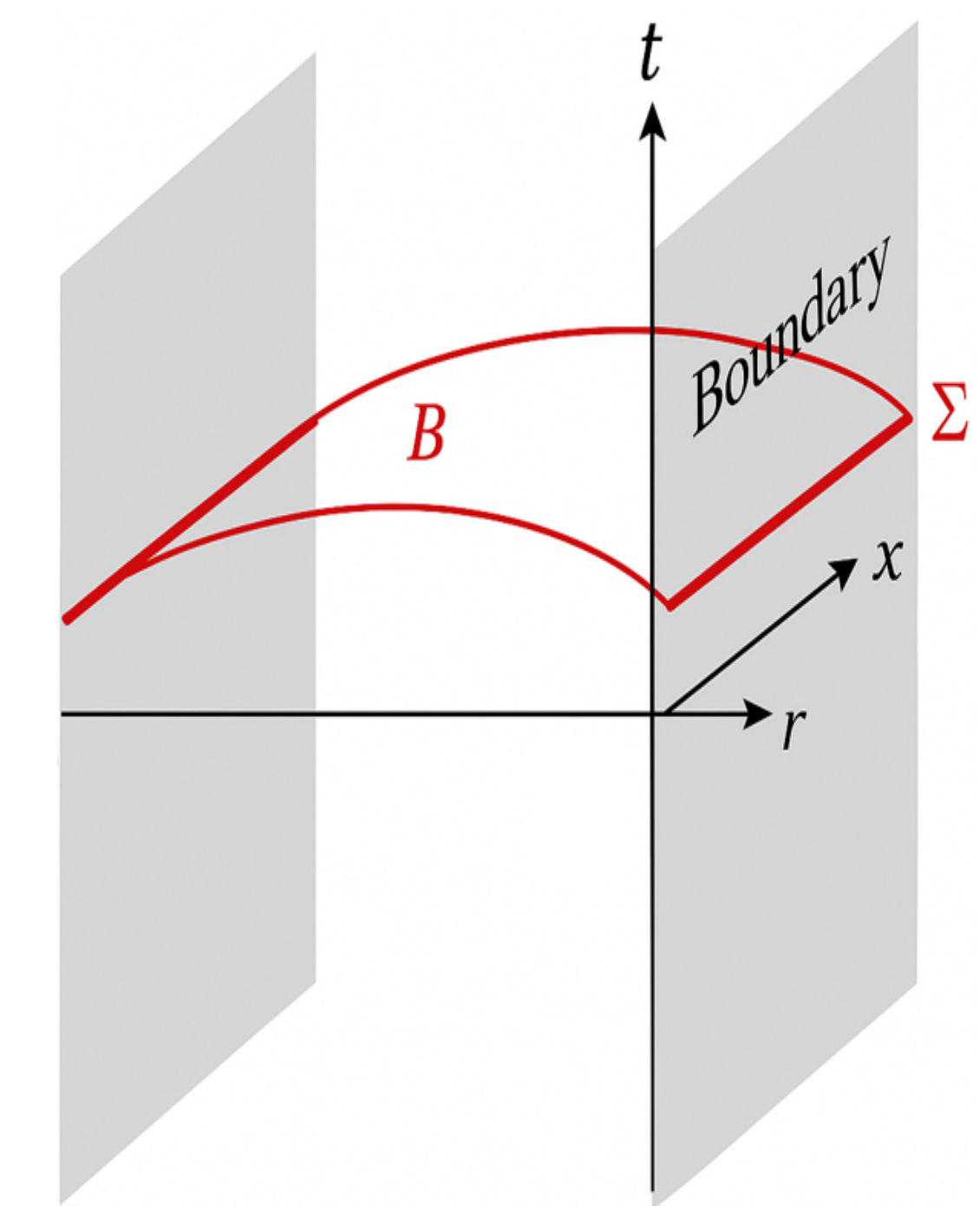


Fig.5: Complexity=Volume (Susskind and Stanford 2014).

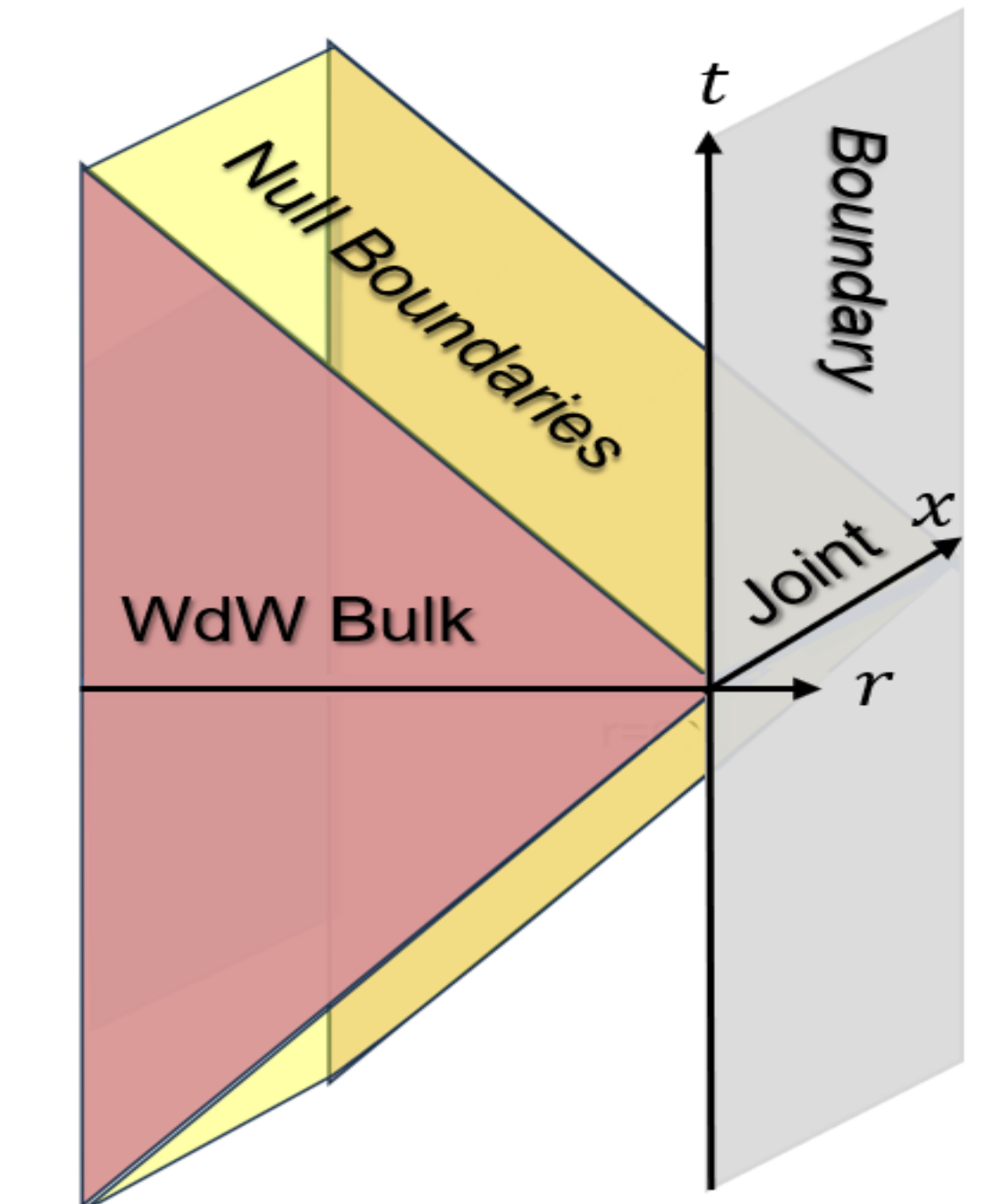


Fig.6: Complexity=Action (Brown, Roberts, Susskind, Swingle, and Zhao 2015)/Complexity=Volume2 (Couch, Fischler, and Nguyen 2016).

RQI and HQI

Relativistic Quantum Information (RQI) studies quantum correlations, and quantum information protocols in relativistic settings.



Holographic Quantum Information (HQI) studies the quantum information and spacetime structures via holographic principle.



arXiv:2508.16466

Our recent work in RQI: Analytic Tools for Harvesting Magic Resource in Curved Spacetime (Yang, Bhattacharya, Zhang, and Mann 2025)

Magic harvested in AdS_{d+1} spacetime

$$M_{\Delta} = \ln(1 + 2\Delta/3) \quad (1)$$

$$\Delta = 2\alpha \sum_{n=0}^{\infty} \frac{\Gamma(d+n-1)}{\Gamma(n+1)} \frac{1}{e^{\frac{\sigma^2}{2}(\Omega^2 + \Omega_n^2)}} \left(1 - \frac{1}{e^{\sigma^2 \Omega \Omega_n}}\right) > 0 \quad (2)$$

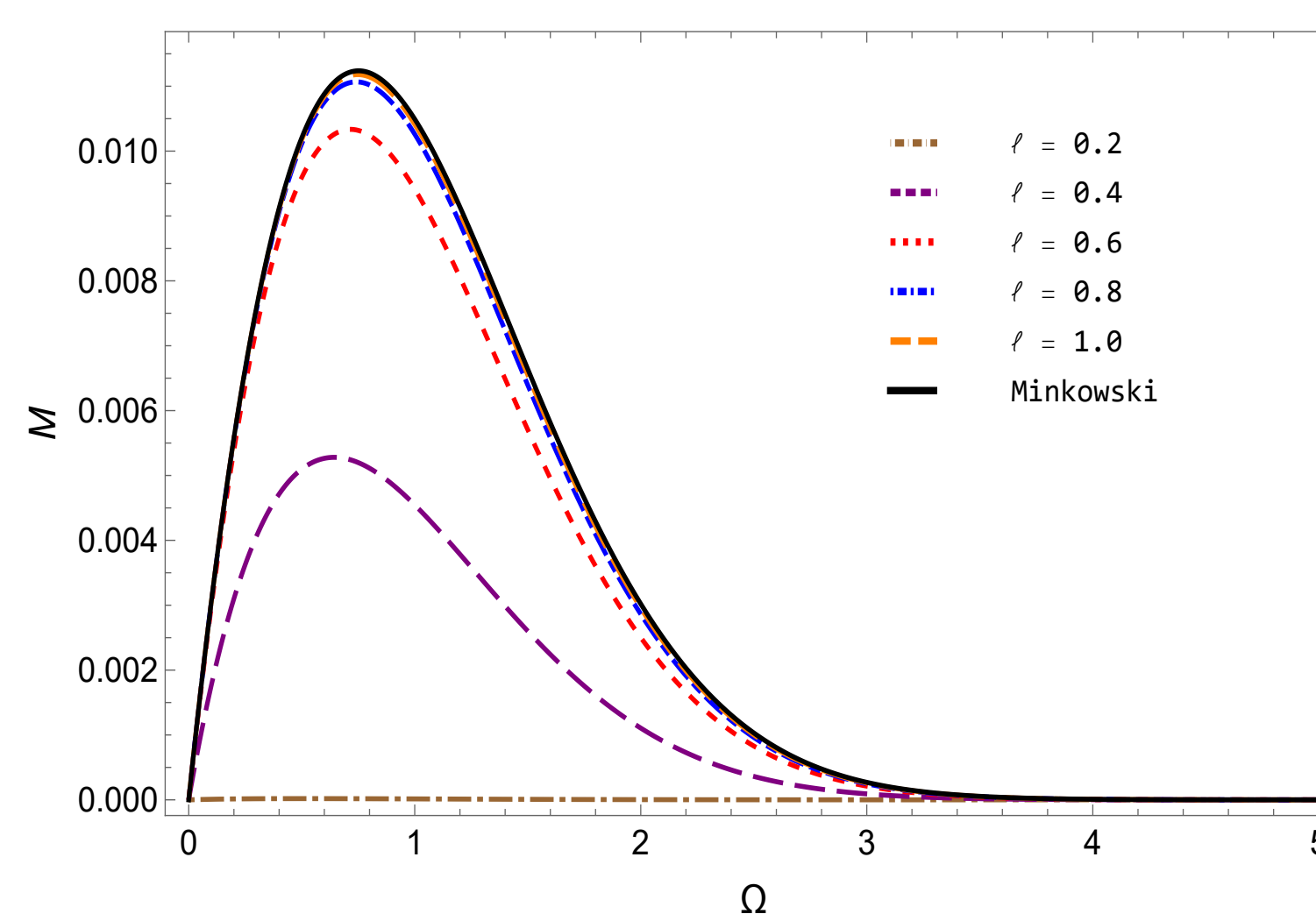


Fig.3: Magic M versus energy gap Ω in AdS_1 with different AdS length scales ℓ .

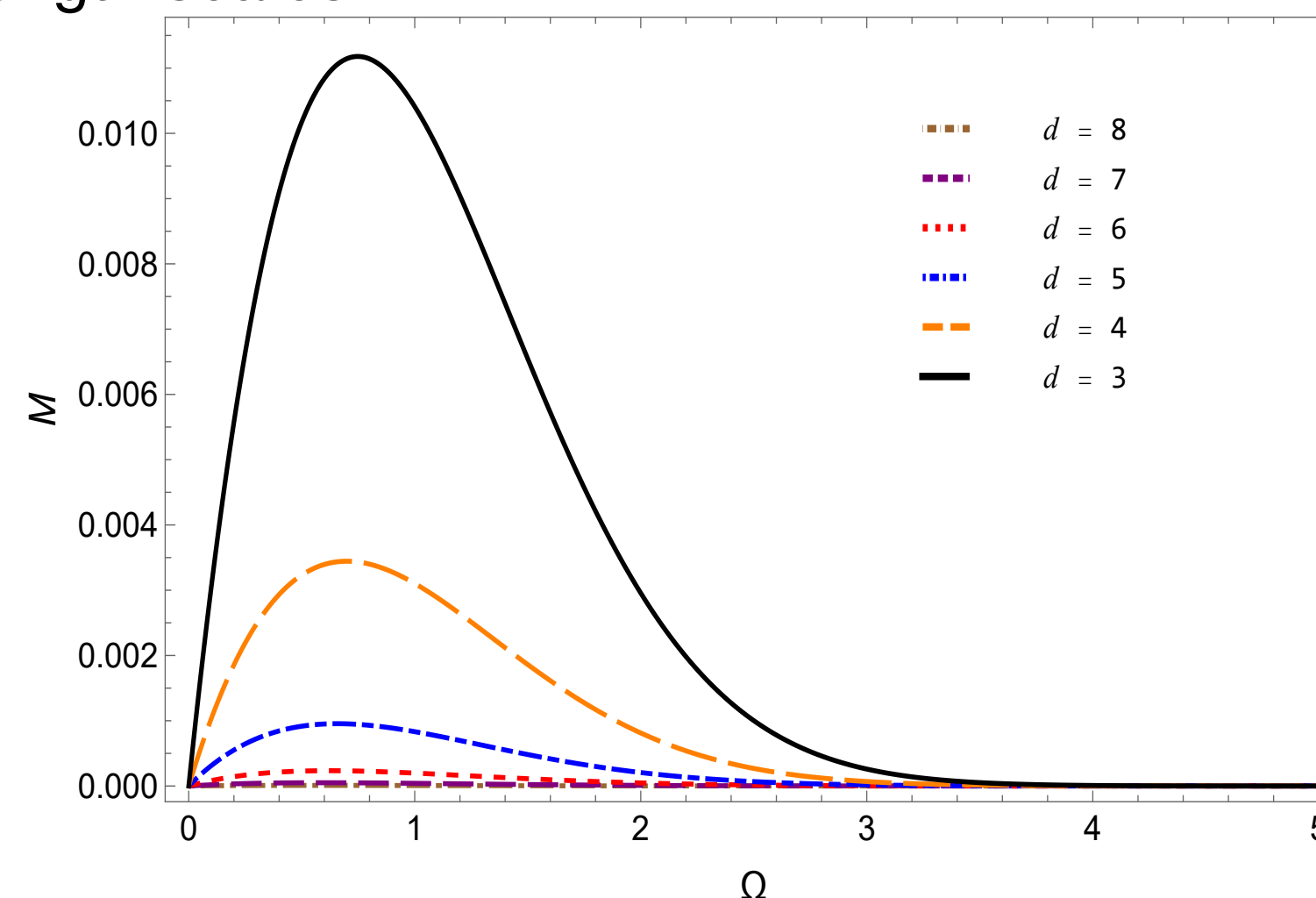


Fig.4: Magic M versus energy gap Ω in AdS_{d+1} with different dimensions d .

Conclusion: Magic can be harvested in AdS spacetime. For higher curvature and dimensions,

- The optimal value moves leftward.
- The amount of magic harvested decreases.

arXiv:2307.08229

Our recent work in HQI: Complexity, Scaling, and a Phase Transition (Yang, and Frey 2023)

The AdS soliton (Witten, Horowitz and Myers 1998) metric

$$ds^2 = \frac{r^2}{l^2} (-dt^2 + d\vec{x}^2 + f(r)d\phi^2) + \frac{l^2}{r^2 f(r)} dr^2, \quad (3)$$

$$f(r) \equiv 1 - \frac{\mu l^2}{r^d} - \frac{Q^2 l^2}{r^{2d-2}} \quad (4)$$

and gauge field

$$A = \sqrt{7-d} Q \left(\frac{1}{r^{d-2}} - \frac{1}{r_0^{d-2}} \right) d\phi, \quad Q \equiv \frac{1}{\sqrt{7-d}} \frac{r_0^{d-2} \Phi}{\Delta \phi}. \quad (5)$$

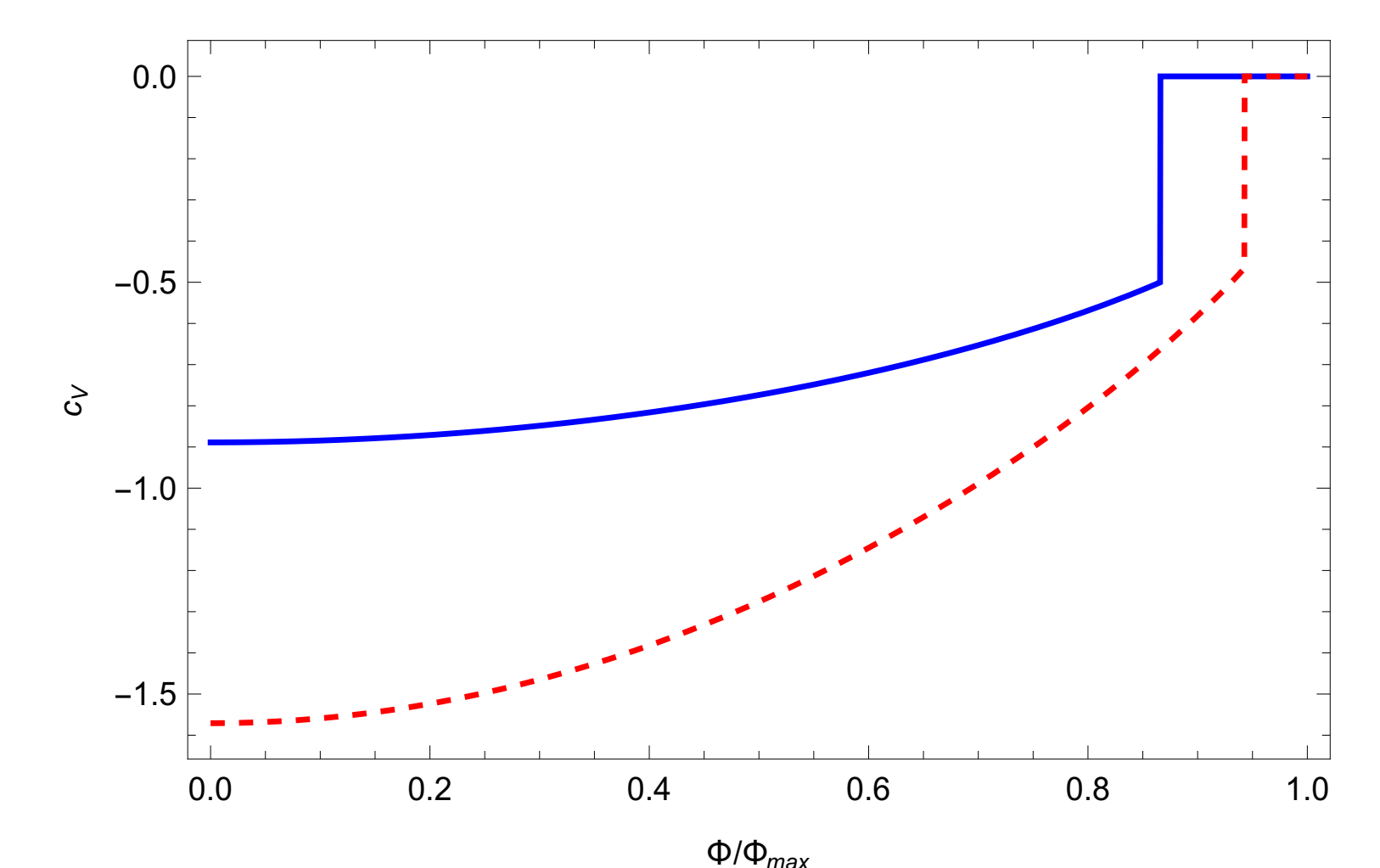


Fig.7: Complexity density for $d=3$ (blue) and $d=4$ (red).

• Phase Transition: There is a transition from the magnetized soliton phase to the periodic AdS phase.

• Scaling Properties: the complexity of formation density for magnetized AdS solitons scales as $1/\Delta \phi^{d-1}$

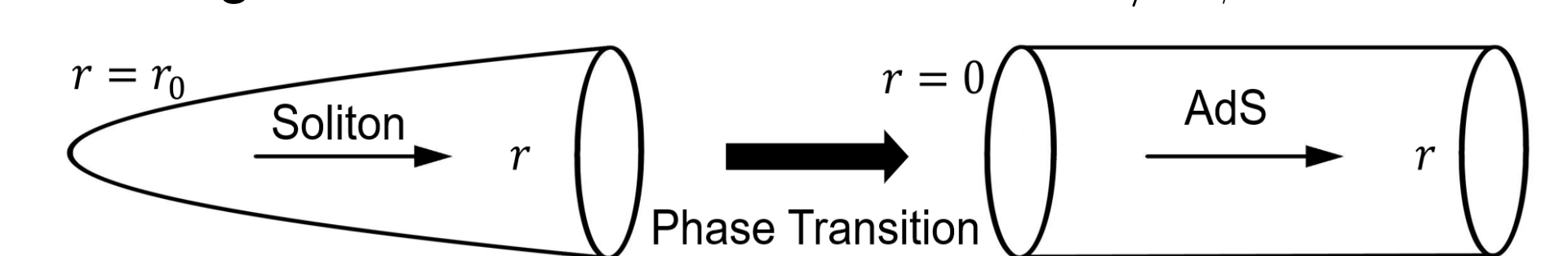


Fig.8: Magnetized Soliton- AdS Phase transition
Feel free to scan the QR code and visit my website <https://link3.cc/jiayue/> I'm open to connections, questions and collaborations!

