

Cosmic Eye

a state-of-the-art view of the universe

version 2.0

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*Youtube "Comic Eye"

Scaling Symmetry

정승원

Scale of Physical values?

- SI units

Length [m]

Mass [kg]

Time [s]

Electric Current [A]

Temperature [K]

Amount of substance [mol]

Luminous intensity [cd]

Scale of Physical values?

- SI units

Length [m]

Mass [kg]

Time [s]

Electric Current [A]

Temperature [K]

Amount of substance [mol]

Luminous intensity [cd]

Scale of Physical values?

- **Natural unit** : $\hbar = c = e = k_B = 1$

Length [m] ~ Mass [kg] ~ Time [s] ~ Electric Current [A]

~

Temperature [K]

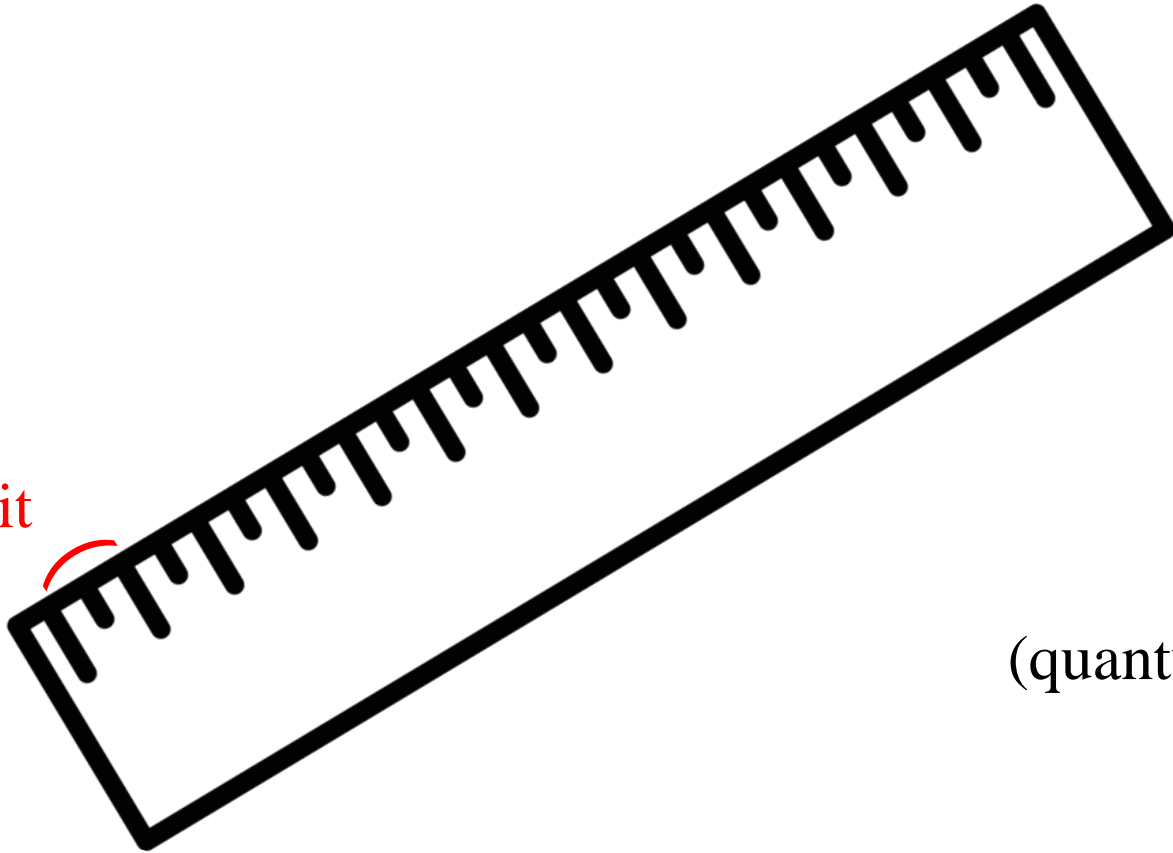
Amount of substance [mol]

Luminous intensity [cd]

Discovery of "universal constants" led to unification of units!

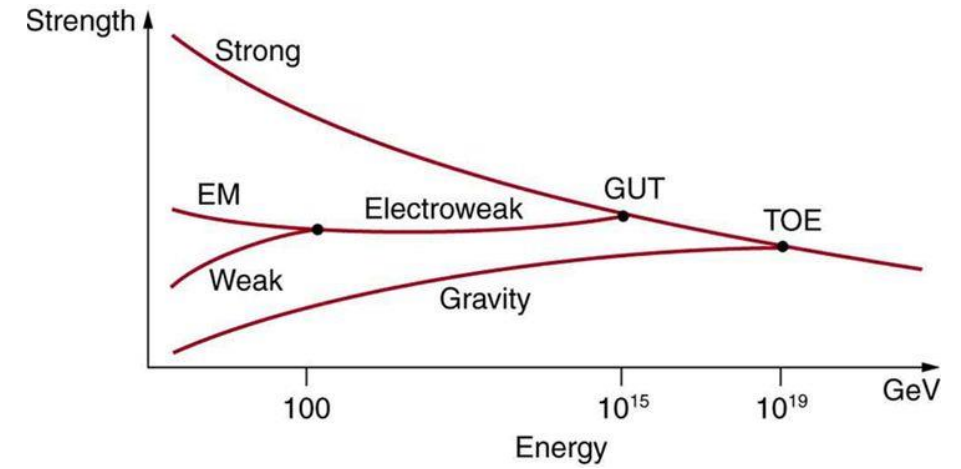
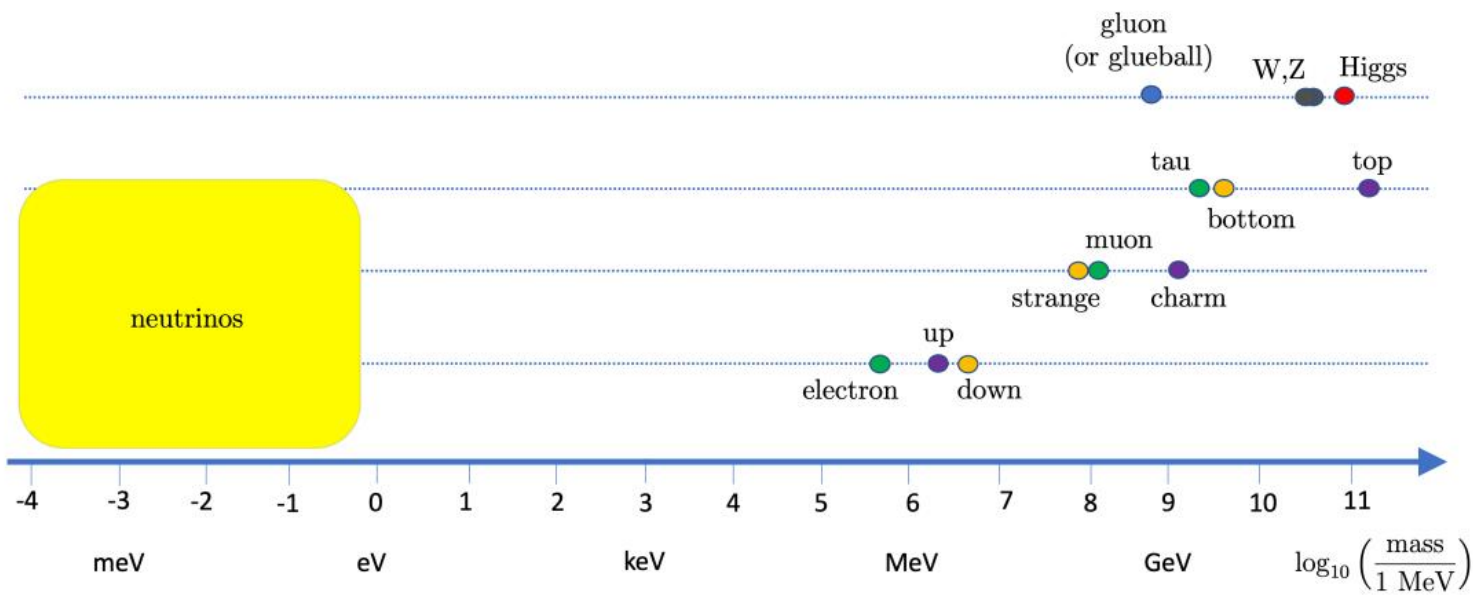
A "unique" physical **scale** with a Planck **unit**

Planck unit



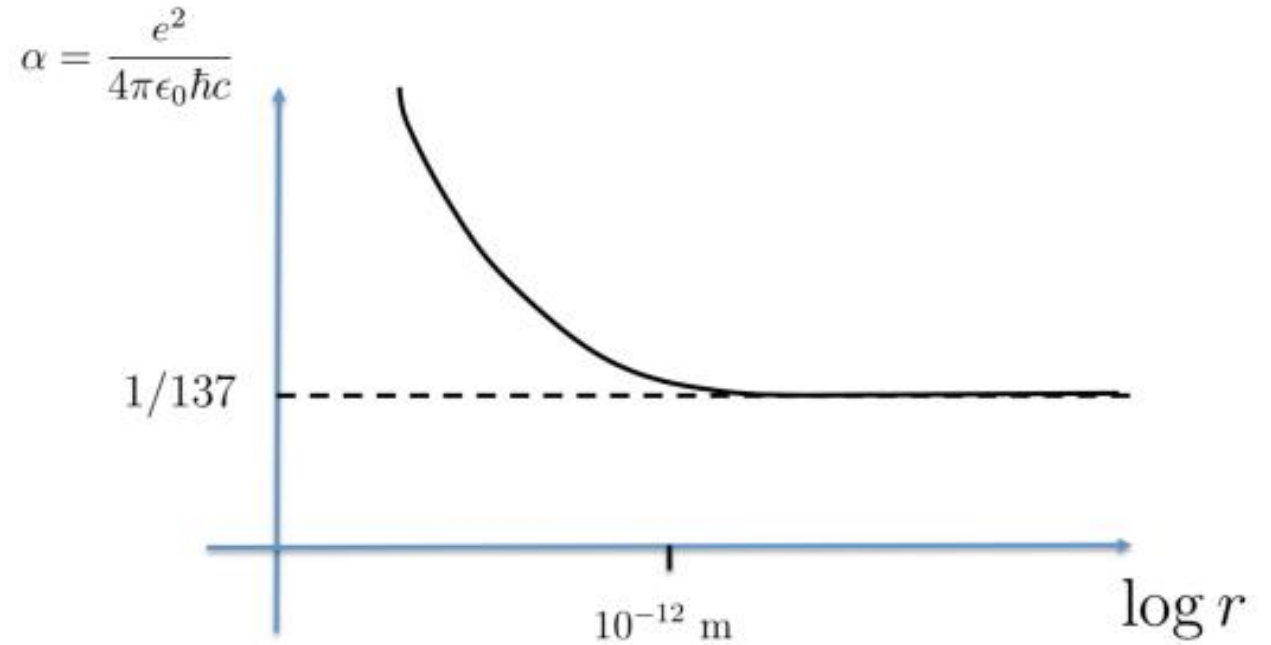
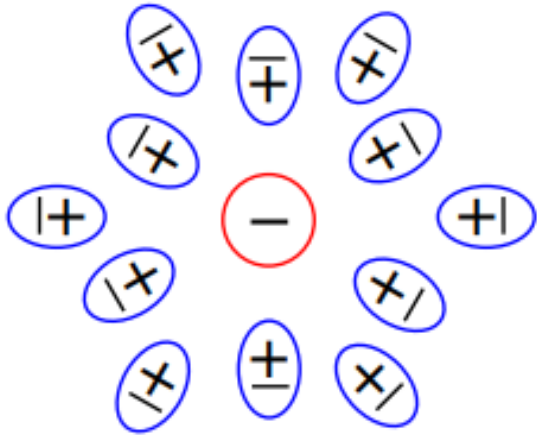
At Planck unit,
(quantum) gravity \approx other forces

Physical regimes are tuned by this "unique" physical scale



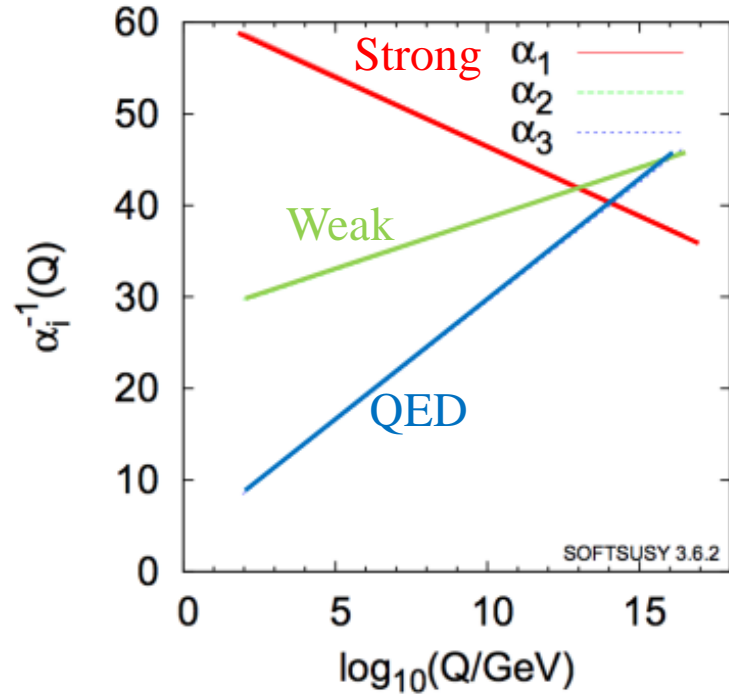
*Image from David Tong's lectures

Renormalization: Running coupling constants



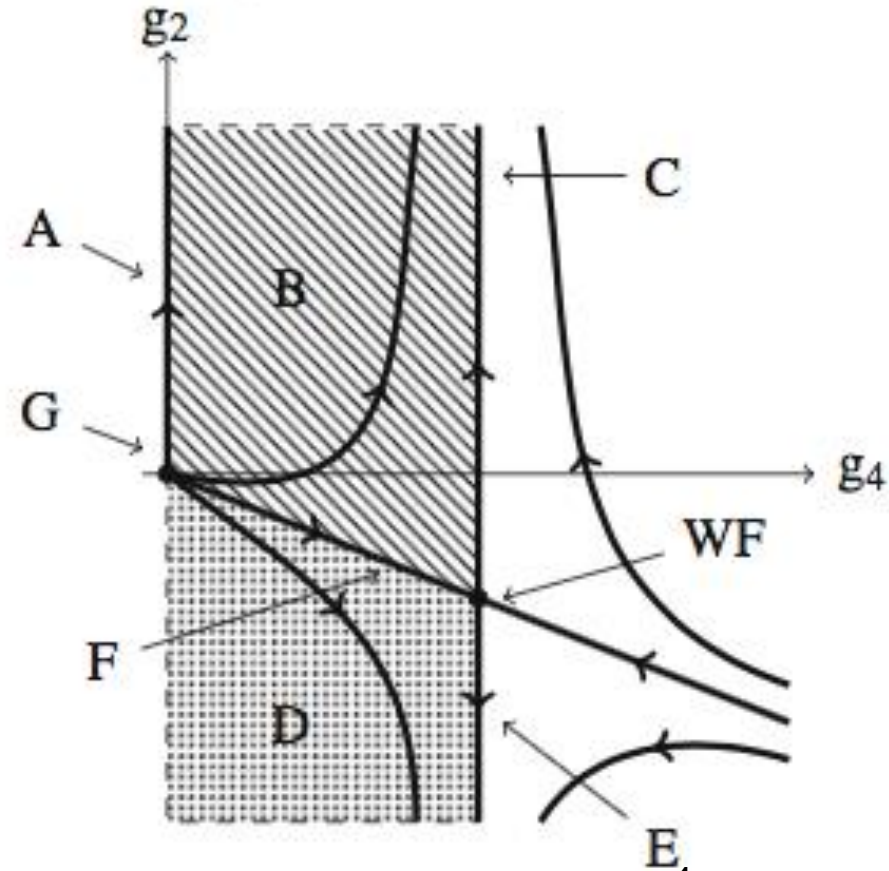
*Image from David Tong's lectures

Renormalization: Running coupling constants



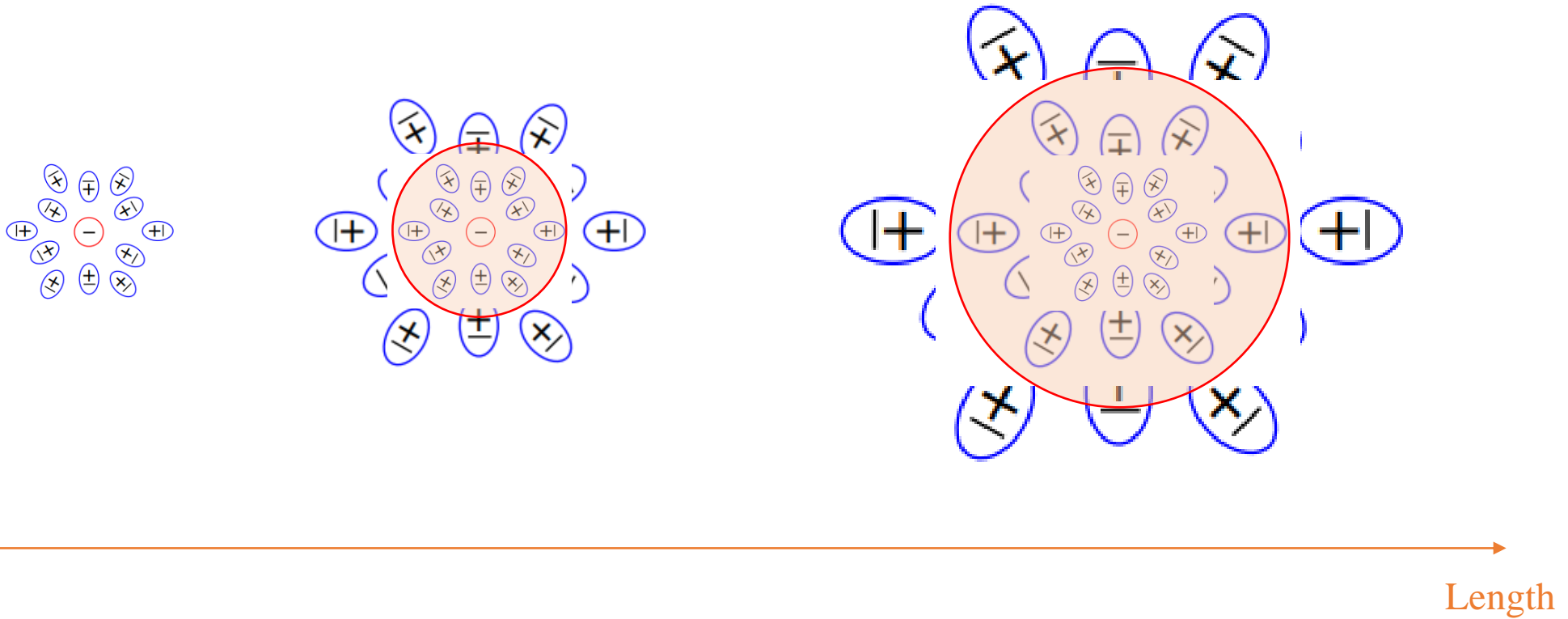
*Image from David Tong's lectures

Renormalization Group Flows (RG Flows)



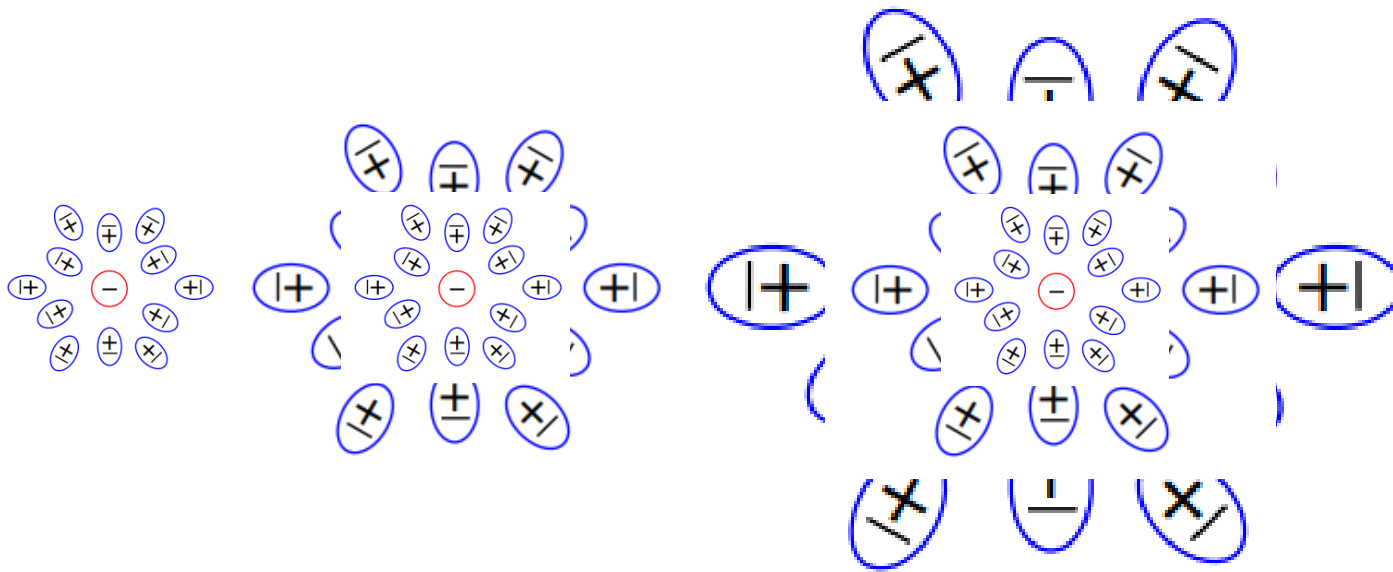
*Wilson-fisher fixed point of ϕ^4 theory

Renormalization: Running coupling constants



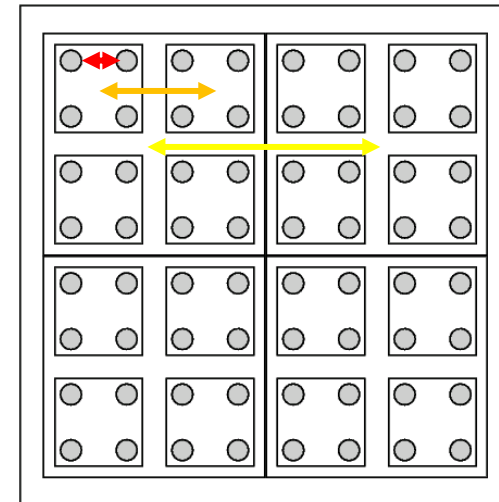
*Image from Wikipedia

Renormalization: Running coupling constants



"Same Equations with **different intensity**"
"Self-similarity"

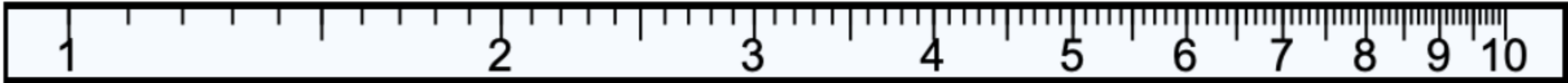
cf. Block spin
from condensed matter physics



*Image from Wikipedia

Scale-invariant theory: Same Equation with **Same intensity**

No favorable length scale!



Continuous Scaling (Dilation) symmetry

Scale-invariant theory: Phase transition

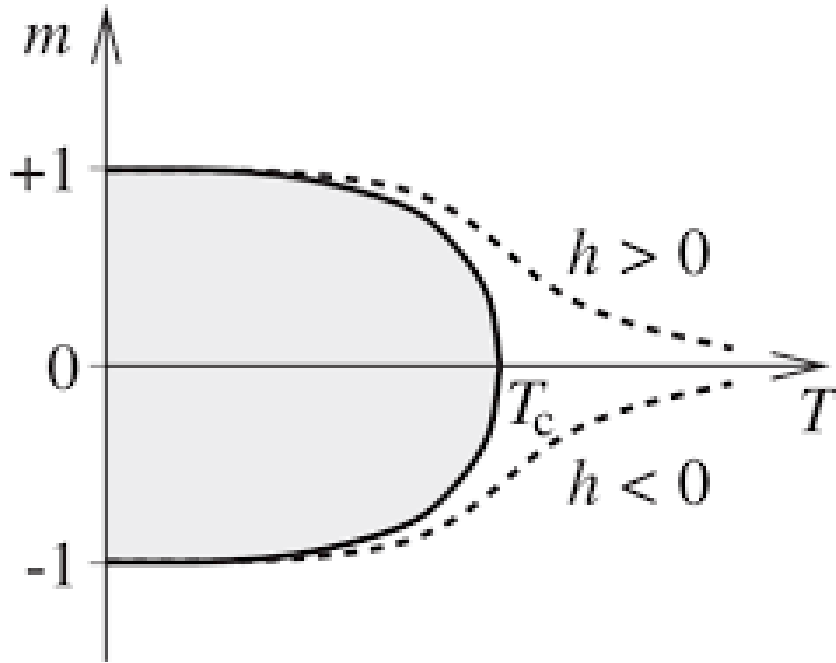


Real space renormalisation group

by Douglas Ashton

www.kineticallyconstrained.com

Scale-invariant theory: Phase transition



$$m \propto (T_c - T)^\beta, \quad \beta = \frac{1}{8}$$

Critical exponents only depend on

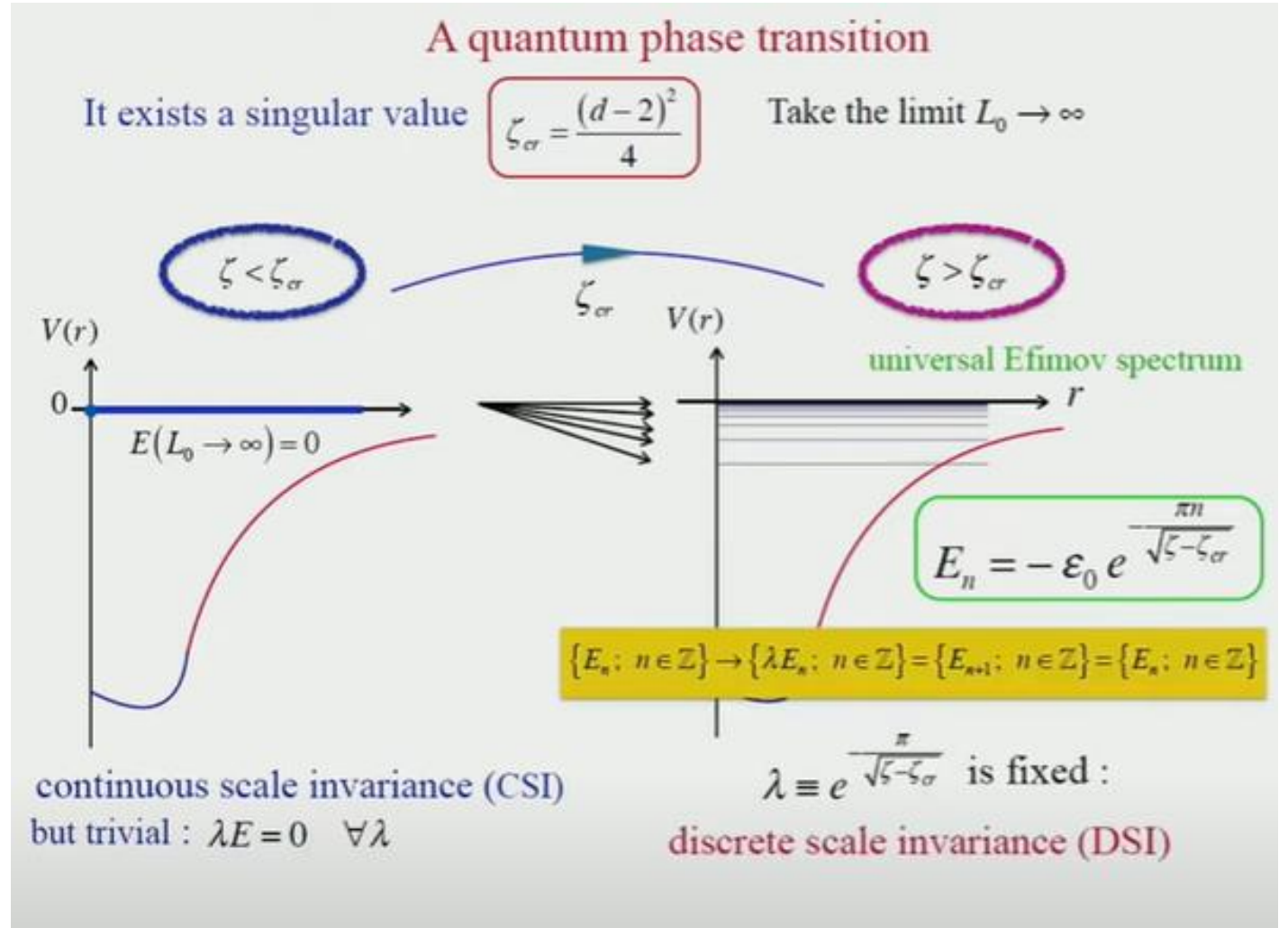
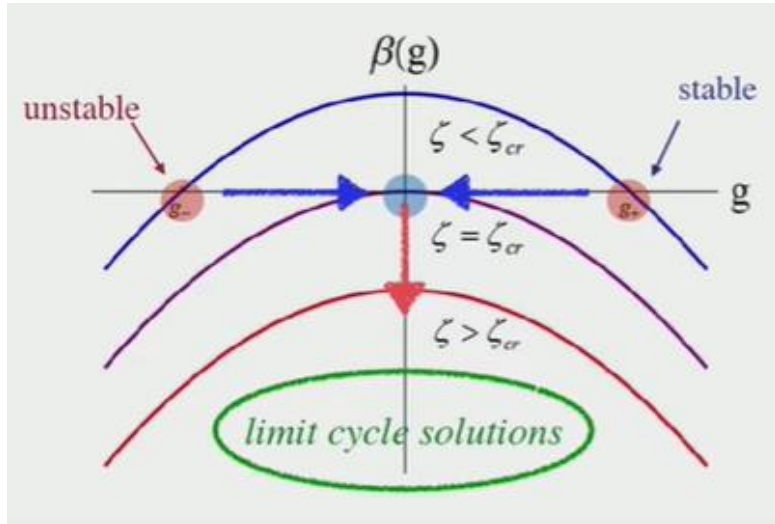
- (1) Dimension of the system
- (2) Range of interaction
- (3) Spin dimension

=> "Universality"

Examples of Fractals: Discrete Scaling symmetry

Ex1. Quantum Phase Transition

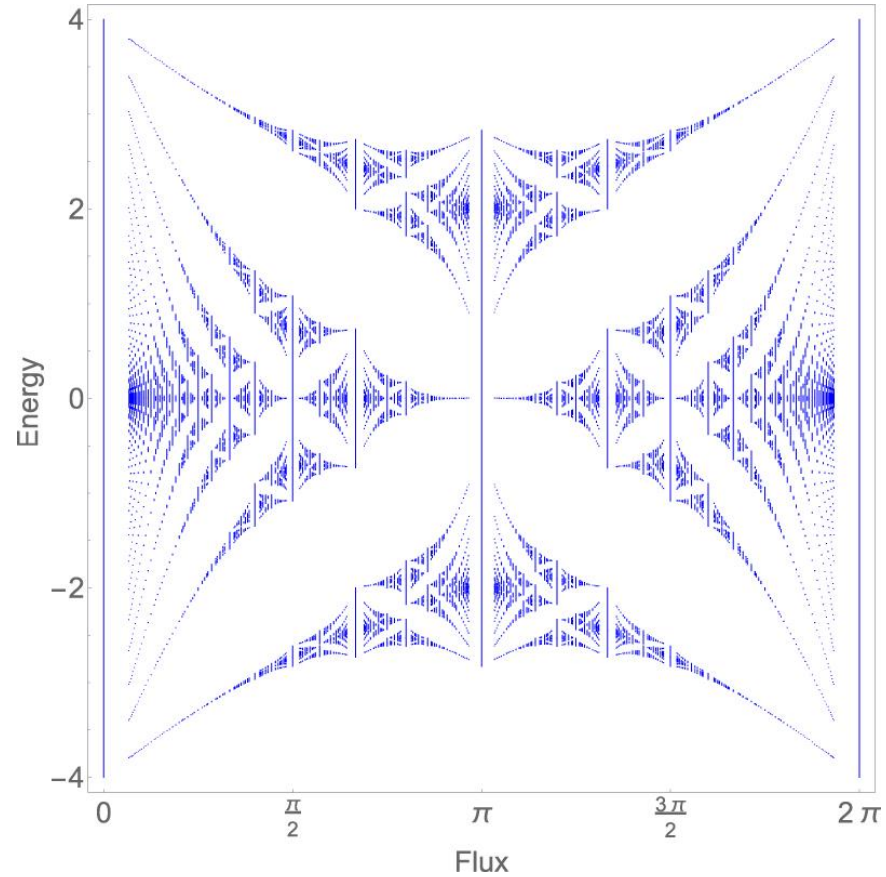
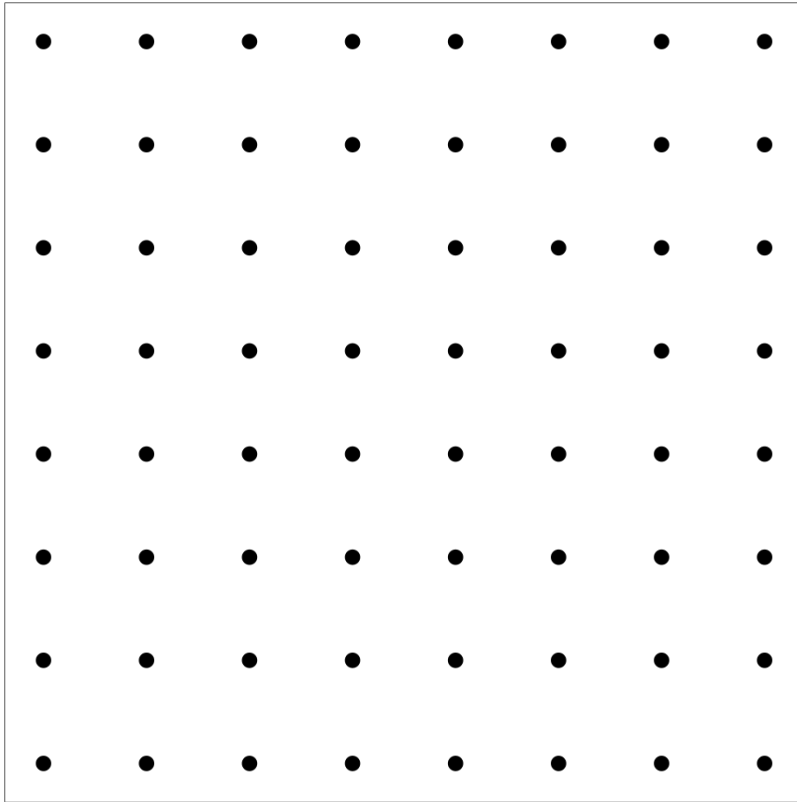
$$\hat{H} = -\frac{\hbar^2}{2\mu} \Delta - \frac{\xi}{r^2}$$



* Youtube "Colloquium: Quantum symmetry breaking : Scale anomaly and fractals"

Examples of Fractals: Discrete Scaling symmetry

Ex2. Hofstadter diagram



Open Q1. Where is Planck unit from?

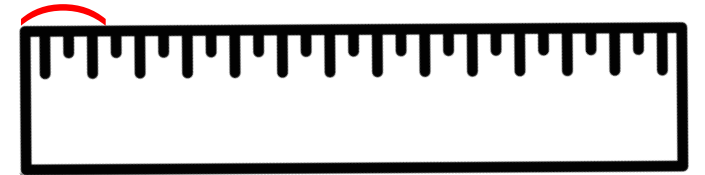
Scale-invariant theory



Symmetry breaking of
Scaling symmetry

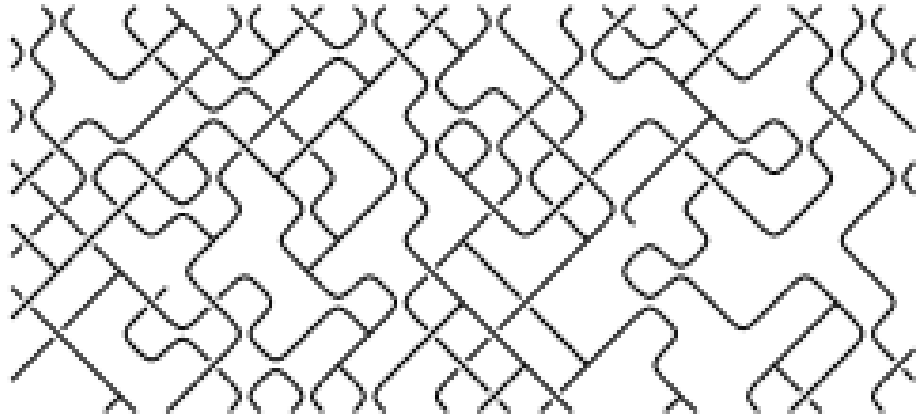


Planck unit



cf. Higgs condensate $\langle \phi \rangle$

Open Q2. Where is Physical scale from?



String-net liquid (Xiao-Gang Wen)

Spatial adjacency

= Entanglement of Quantum Information

Q&A