Journeys through the Zeptouniverse:

Theoretical Particle Physics—

The Magic of Multiple Perspectives

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THE MAGIC OF PHYSICS

Physics@Veldhoven · 18 January 2021

The Great Lesson of 20th Century Science

The human scale of space and time is not privileged for understanding Nature, and may even be disadvantaged.

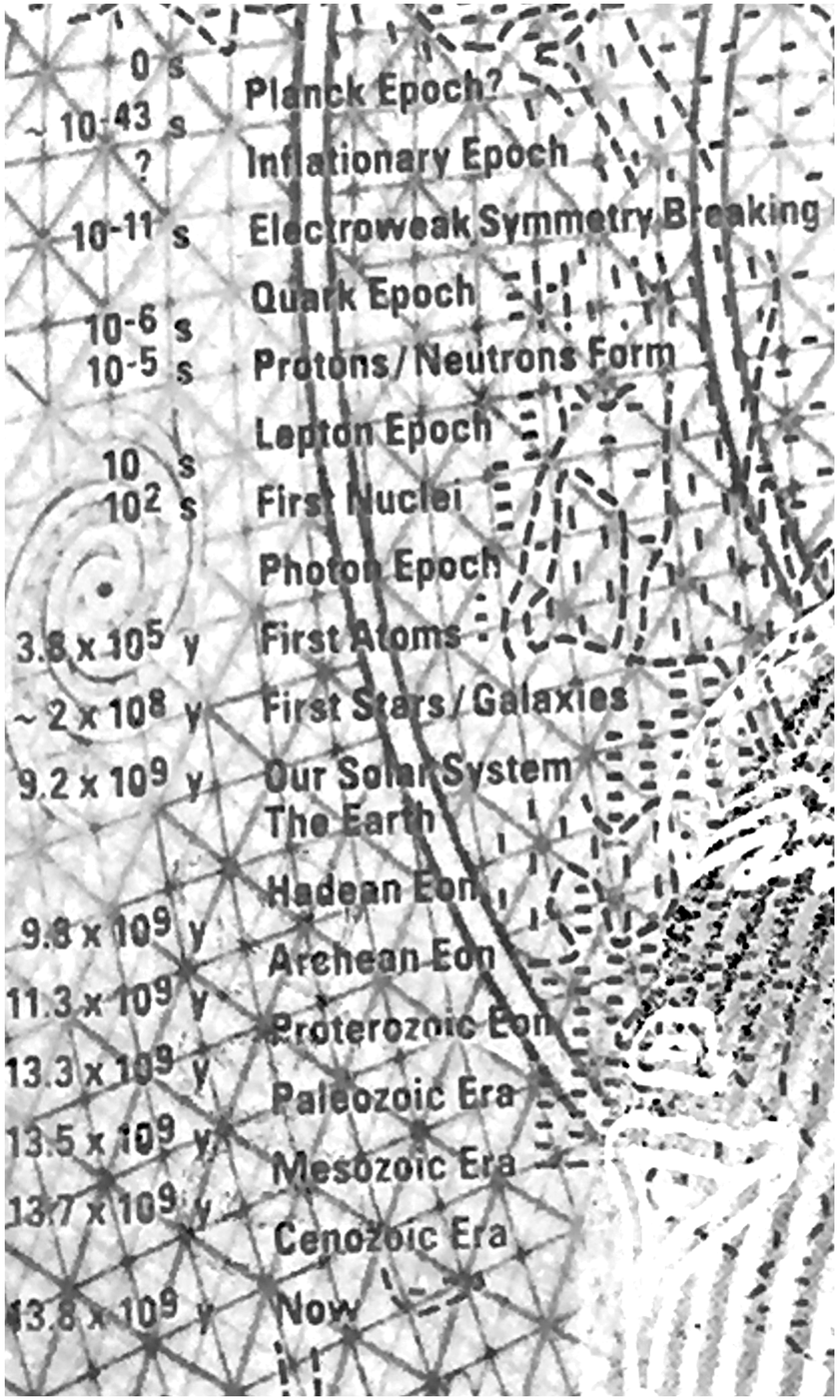
The discovery that the human scale is not preferred is as important as the discoveries that
our human location is not privileged (Copernicus)
and that there is no preferred inertial frame (Einstein),
and will prove to be as influential.

Lifetimes

$^{136}\mathrm{Xe}_{\beta\beta\nu\nu}$: 3.2×10^{21} yr

$^{124}\mathrm{Xe}_{\mathrm{ECEC}\nu\nu}$: 2.6×10^{22} yr

p : $> 10^{29-33}$ yr



Apollo 8 · Earthrise from lunar orbit · 24 December 1968

Sturnus vulgaris / Starling / Spreeuw

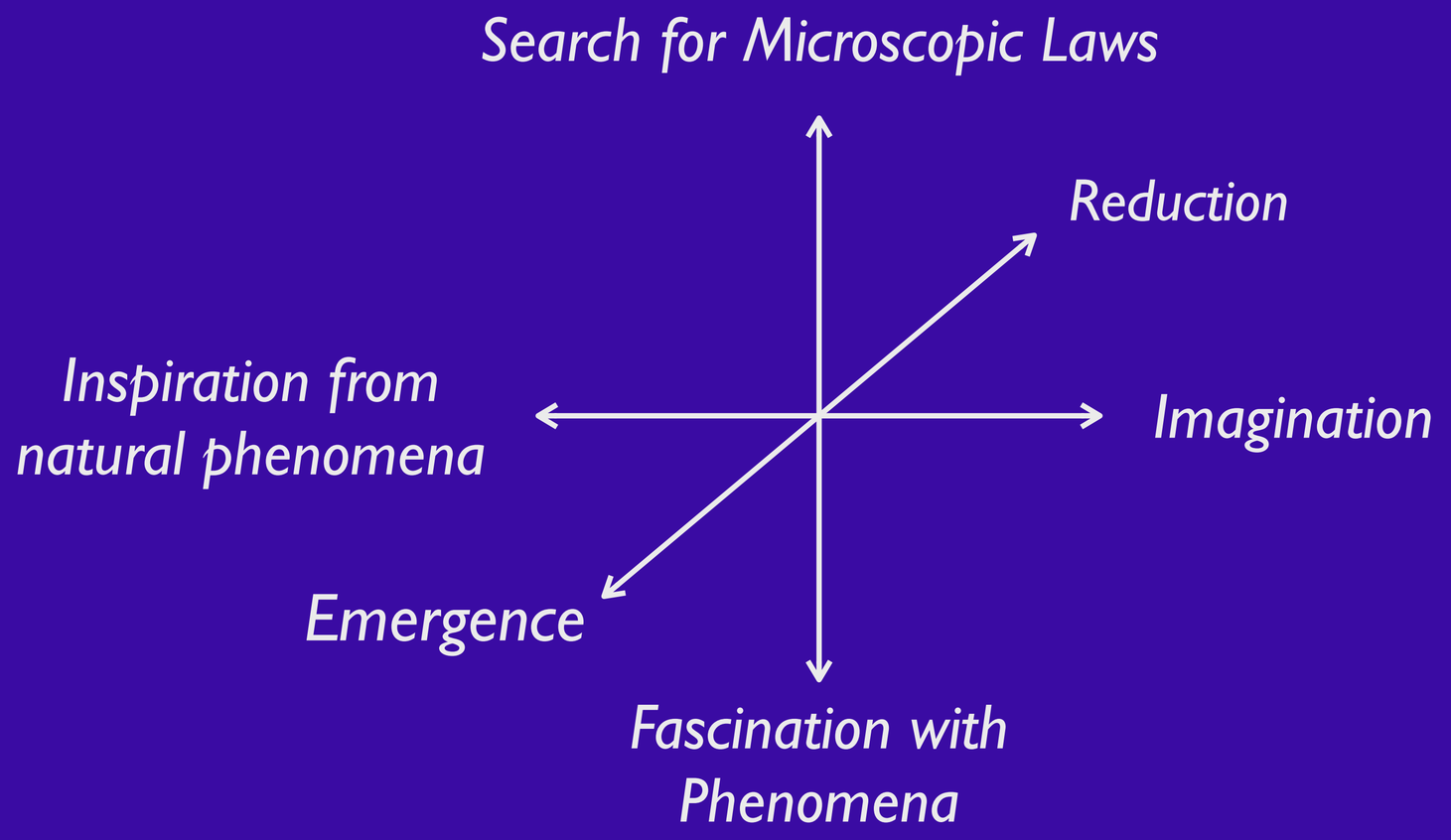
DNA: relationship to other creatures

Murmuration of starlings / spreeuwenzwermen

Scale-free critical system?

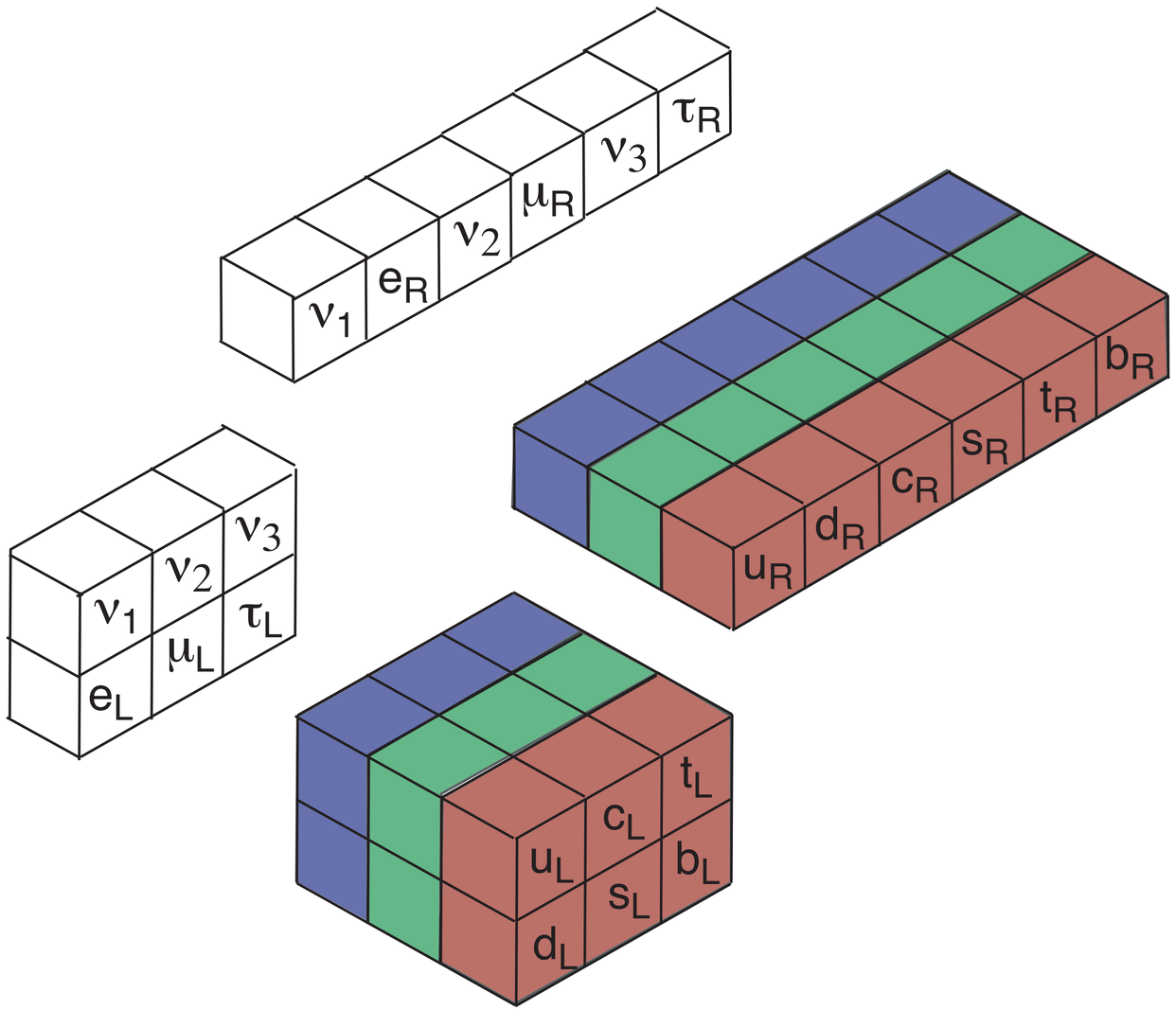
Styles of investigation

Experiment · Observation · Phenomenology · Formal Theory



Where is your home base? How far do you roam?

Our Conception of Matter



Spin-1/2 quarks and leptons, pointlike at attoscale *(nanononanoscale)* ~ 1 TeV

Emmy Noether's Theorems (1918)

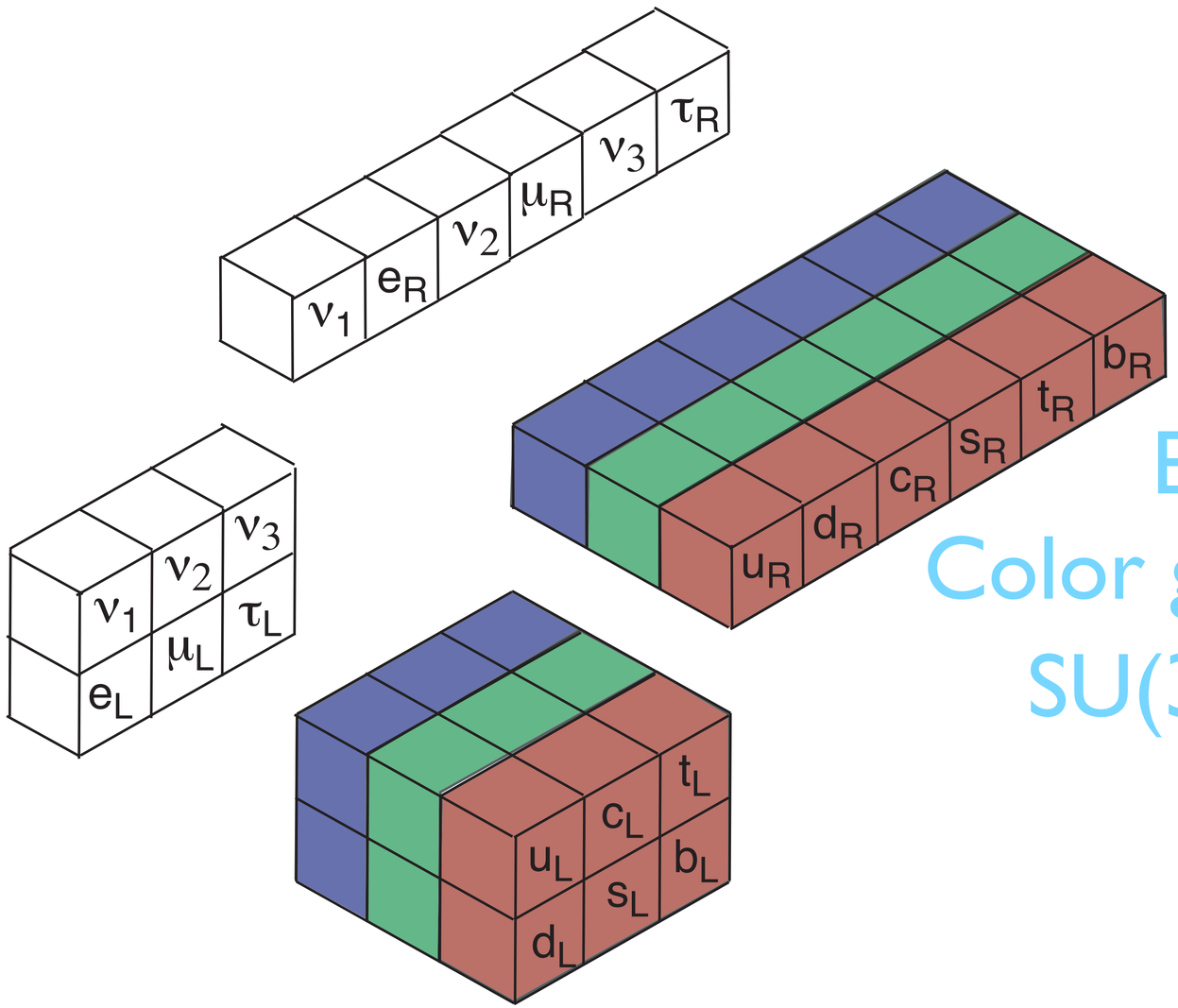
Global Symmetries $\Longleftrightarrow$ Conservation Laws

Local Symmetries $\Longleftrightarrow$ Interactions

Example 1:
QM phase symmetry
$U(1)_{EM} \Longleftrightarrow$ QED

arXiv:1902.01989

Our Conception of Matter



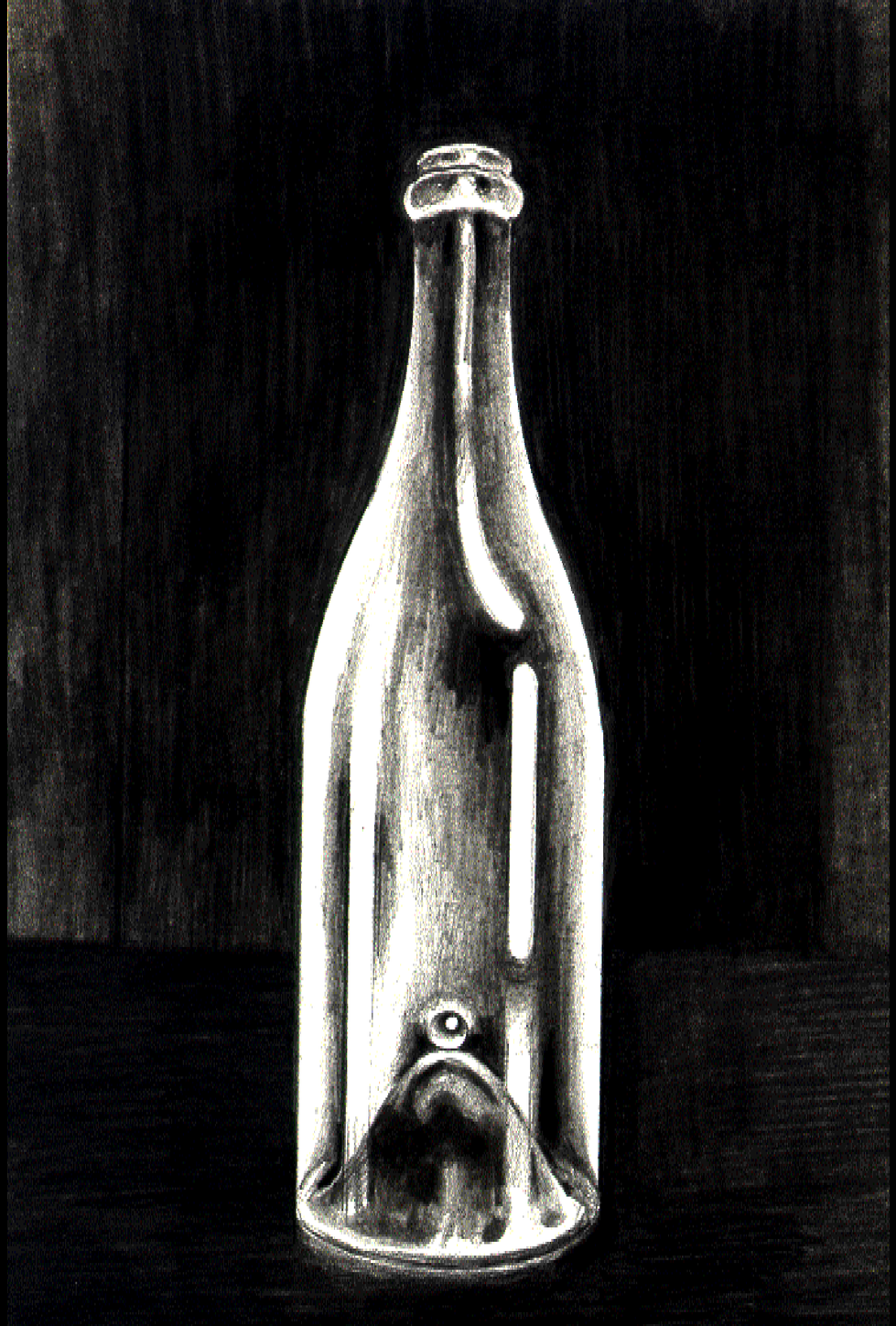
Example 2:
Color gauge symmetry
$SU(3)_c \Longleftrightarrow QCD$

Interactions: $SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$ gauge symmetries

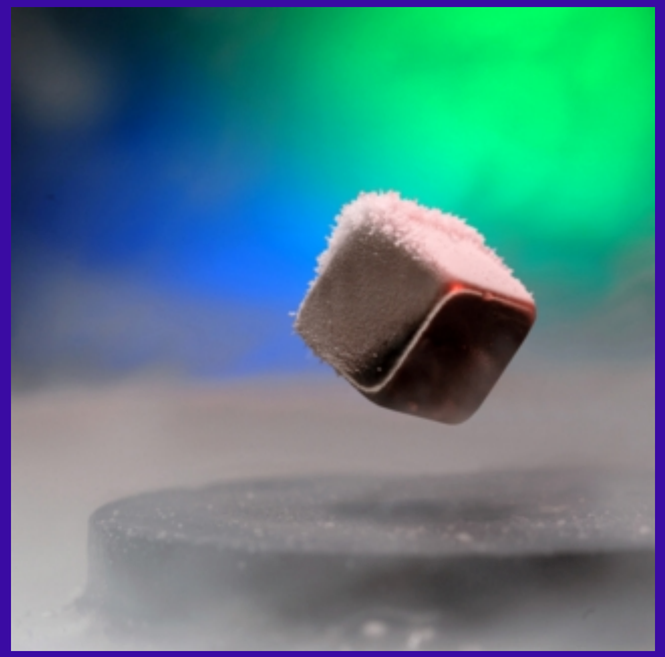
Symmetric laws

need not imply

symmetric outcomes.



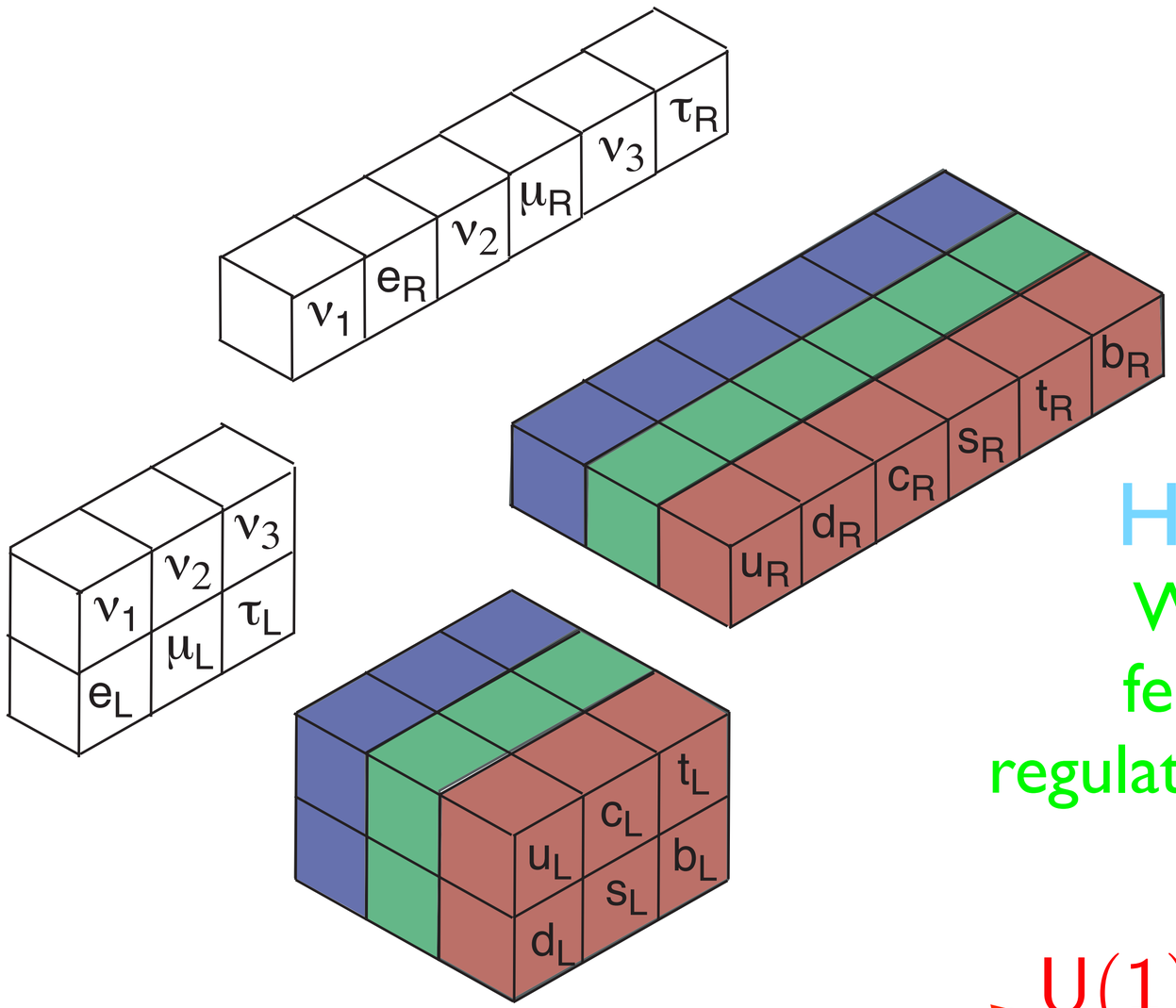
Meißner effect inspires Electroweak Symmetry Breaking



Photon acquires mass in superconducting medium

Ginzburg–Landau Model for Brout–Englert–Higgs (et al.) Mechanism

Our Conception of Matter



Avatar:
Higgs Boson
W & Z masses
fermion masses
regulates WW scattering

$U(1)_{EM}$

Interactions: $SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$ gauge symmetries

Parameters of the Standard Model

3	Coupling parameters, α_s, α_{em}, $\sin^2\theta_W$
2	Parameters of the Higgs potential
1	Vacuum phase (QCD)
6	Quark masses
3	Quark mixing angles
1	CP-violating phase
3	Charged-lepton masses
3	Neutrino masses
3	Leptonic mixing angles
1	Leptonic CP-violating phase (+ Majorana phases?)
26^+	Arbitrary parameters

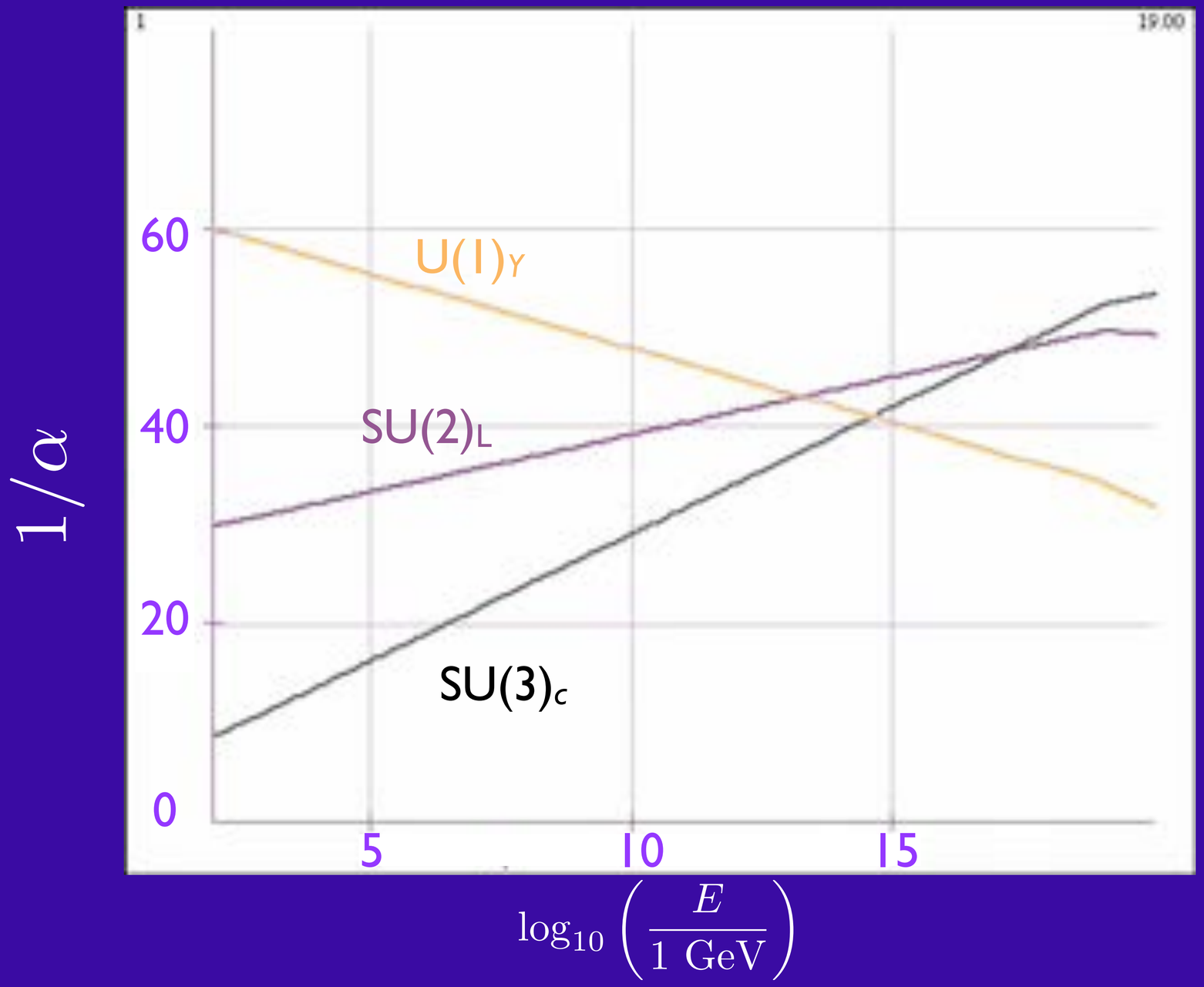
Problem of Identity:
What makes a top quark a top quark,
an electron an electron, etc.?

Changing energy / distance scales
in experiment (accelerators)
and theory (renormalization group)
is one important path to new physics

Ultrasensitive experiments another:
virtual access to very high energy scales

What are relevant scales, degrees of freedom?

Changing energy scales = new perspectives



In the heart of this session:
Searching for clues to a more complete understanding
through high-energy reactions,
questions surrounding the Higgs boson,
and flavor physics of quarks, charged leptons, neutrinos

For 120 questions from me, see
"Perspectives and Questions"