What could the LHC teach us on space-time structure?

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International Conference on New Frontiers in Physics
August 2015

Outline

1. Motivation
   - In front of the desert?
2. Synthetic bottom-up approach
   - Hierarchy stabilization and extrapolation to M_{Pl}
   - Mirror fermions: a strong case
3. Analytical top-down approach
   - Space-time structure and nature of particles
   - Complexity and emergence
4. Conclusions

A critical conjuncture

- After waiting for several decades,
  we may at last have direct evidence of BEH mechanism
- but: $M_{Pl}/M_{Higgs} \sim 10^{17}$
- What preserves such a huge hierarchy?
- If this hierarchy reflects an energy "desert", the LHC is one of our last chances, for many decades to come, to find indirect clues for Planck-energy Physics

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Discover fundamental principles

- LHC findings $\longrightarrow$ particular hierarchy problem solution
- Implications to Planck-scale Physics
- Discovery of fundamental principles pertaining to space-time structure and nature of particles

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Some known alternatives

- Large extra dimensions
  Stabilizer: size of extra dimensions
- Known particles have spin-zero partners (SUSY)
  Stabilizer: space-time symmetry - Interaction: weak
- Known particles have mirror partners (Katoptrons)
  Stabilizer: gauge symmetry - Interaction: strong

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  Planck scale is effectively brought down to the weak scale
- SUSY
  Particles @ M_{Pl} are strings moving on a continuous space-time background
- Katoptrons
  Particles @ M_{Pl} are vacancies within an emergent dynamic discrete space-time lattice
- Last two solutions share in principle
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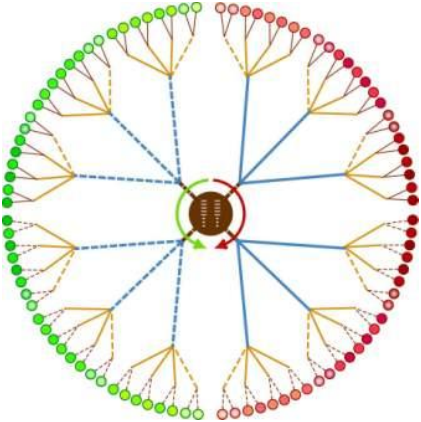
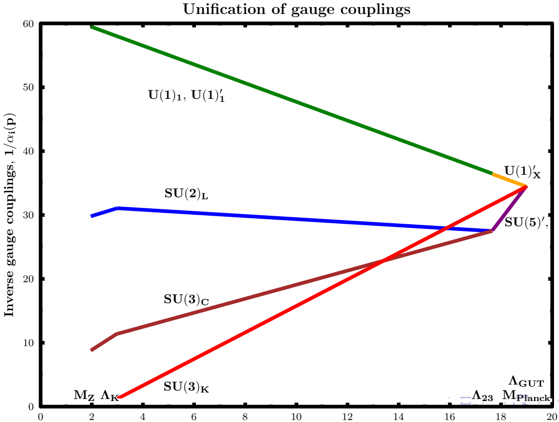
Archetypical dendrite



$1\ \mathrm{TeV} \sim M_{\mathrm{Pl}} \exp\left(-\alpha_{M_{Pl}}^{-1}\right)$ (G.T. 2011)

$$E_8 \times E_8'(\Lambda_{GUT}) \to SU(3)_C \times SU(2)_L \times U(1)_1 \times U(1)_1' \times SU(3)_K \to$$
$$(1\ \mathrm{TeV}) \to \text{Standard Model}$$



Experimental signatures @ the LHC

- Direct: Bosonic (spin 0,1) bound states of mirror fermions
  QCD analogues: Mirror $\sigma \sim \sigma^K$, Mirror $\rho \sim \rho^K$
  Decays: $\rightarrow$ heavy difermions ($t\bar{t}, \ldots$), dibosons:
  ATLAS and CMS excesses @ 0.125 (σ^K) & 1.9 (ρ^K) TeV

- Indirect: Deviations from SM predictions due to QM

  Importance of heavy fermions:
  top-quark asymmetries, lepton universality,
  V_{tb} not assuming 3×3 CKM matrix unitarity,

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What would such signatures imply
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The questionable role of infinity

- Descartes: works in space continuum.
  Kant: it can never be proven whether space is infinite nor whether particles can be infinitely split!
- Leukippos, Demokritos : infinite shapes of atoms
  Anaximandros: infinite size of Space,
  infinity as a primordial Cause.
- Plato: number of possible element shapes is five.
  Dimensions of known fermion representations are finite.
  Extend finiteness to the number of each point's neighbors?
- Aristotle: particles are extended and not point-like.
  Strings on a continuum background vs. lattice vacancies?

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Optimal lattice

- Arrogance of Continuum (infinite neighbors for points): inability to cope with Complexity (finite neighbors for points)
- Imagine points as n-dim. unit spheres → Kissing number problem: find max. number of non-overlapping n-dim. unit spheres in (n+1)-dim. Euclidean space touching another given unit sphere.
- Solution of sphere-packing problem: root lattices of SU(2), SU(3), SU(4), SO(8), SO(10), E_6, E_7, E_8 for d=1, 2, 3, 4, 5, 6, 7, 8

For 8 < d < 16, optimal packings are non-lattice

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Intriguing characteristics I

- Emergence of dynamical space-time as a world crystal:
  Percolation model based on the E_8 root lattice
  leading to quantum gravity via

  a discretized version of the Hebecker-Wetterich (2003)
  spinor-gravity action

- Explanation of space-time symmetry and dimensionality,
  number of particle generations and gauge symmetries

- Unification paradigm solving the hierarchy problem
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  chiral index of a model of free lattice fermions is zero

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Intriguing characteristics II

- Discreteness provides clues for the cosmological constant, the initial entropy of the Universe and non-locality in QM
- Relevance of complexity theory to structure formation (galactic spirals and bars, intergalactic voids, ultra-high-E cosmic rays etc.)
- Correspondence of Dark Matter surrounding galaxies to amorphous, glass material around crystalline regions
- Inflation from compactification of extra dimensions
- Particles $\leftrightarrow$ vacancies: particle number in the Universe, black-hole information paradox

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Conclusions

- Space-time points: exact, distinct copies of an archetypical One or Monad, the neo-Platonic epitome of the Parmenides-Plotinus 7-century-long era
- Allow space-time-crystal and vacancy-particle symmetries to emerge from optimal connections between these entities
- Axiomatic formulation based on the

Optimal Connectivity Principle:

Acts of archetype's copying and connecting ($\sim \Lambda$)
replace energy/action minimization and
lead to optimal information propagation
(applicable also to coding theory, cognitive science etc.)

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“Beauty is eternity
contemplating itself in a mirror..."

K. Gibran (1923)

Acknowledgements

This research has been co-financed by the European Union (European Social Fund -ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: THALES. Investing in knowledge society through the European Social Fund.

Only if question arises

Dimensional arithmetics

String theory:
d_0 = **24** (Leech)+ **2** (world-sheet) = **26** (spacetime: background)
$d_{c1} = d(E_8 \times E_8$, R) = **16** (symmetry underutilization?)
d_{c2} = **6**
$d_{spacetime} = d_0 - d_{c1} - d_{c2} =$ **4** (R)

Spinor gravity applied to Katoptron theory:
$d(E_8\ cluster) = \mathbf{8}\ (R) \longrightarrow d(E_8, C) = \mathbf{8}\ (C) \rightarrow$
crystalization: $d_0 = d(E_8 \times E_8'$, C) = $2d(E_8, C)$= **16** (C)
$d_c = d(E_7 \times E_7'$, C) = **14** (C)
$d_{spacetime} = d_0 - d_c =$ **2** (C) = **4** (R) (spacetime: dynamical)

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Previous work

- T.D. Lee and C.N. Yang (1956): Mirror fermions
- J.C. Pati and A. Salam (1973): Coupling unification
- F. Gursey and P. Sikivie (1976): E_7 GUT (W. Killing 1888)
  N.S. Baaklini; I. Bars and M. Gunaydin (1980): E_8 GUT
- S. Weinberg (1976), L. Susskind (1979):
  Dynamical Higgs mechanism
  Universe: a "superconductor", $Higgs \sim < \bar{\Psi}\Psi >$
- F. Wilczek and A. Zee (1982):
  Dynamical electroweak symmetry breaking
  by mirror fermions

Spinor-gravity metric: inherently quantum-mechanical

- $g_{\mu\nu} =< \tilde{E}^m_\mu(x) >< \tilde{E}_{\nu m}(x) > \neq 0$ only for $\quad m,\mu,\nu = 0,...,3$
- $\tilde{E}^m_\mu(x) \sim \bar{\Psi}(x)\gamma^m\partial_\mu\Psi(x), \qquad m,\mu = 0,...,d \geq 3$
  A. Hebecker and C. Wetterich (2003)
- Physical distances: induced by fermion correlat. functions; spacetime: dynamical, non-perturbat., not just background
- $S_f \sim \int d^d x \det(\tilde{E}^m_\mu) \rightarrow$
  $S_{<mean\ field>} \sim \int d^d x \det(< \tilde{E}^m_\mu >)(1- < \tilde{E}^\mu_m > \tilde{E}^m_\mu + ...)$