Strong and gravitational forces: what do they have in common?

Artan Boriçi

Outline of the talk

- Lattice gauge theory in Albania
- Lattice field theory
- Interaction of colorless charges
- Interaction of color charges: QCD string
- QCD string at high temperatures: black holes
- Gravitation as entropic force
- Discussion

Lattice gauge theory in Albania

Timeline:

2003: Founding with two members: AB and Alban Allkoçi

2003-2006:

- Optimal algorithms for overlap fermions
- Release of QCDLAB 1.0

2007-2008: Formulation of ultralocal chiral fermions on the lattice

2009-today: New members: Dafina Xhako, Rudina Zeqirllari

- Multigrid algorithms for overlap fermions
- Hadron spectrum with ultralocal chiral lattice fermions

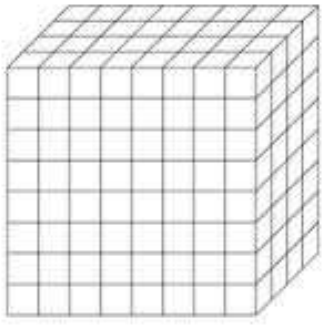
Next: Lattice gauge theory and quantum gravity

Lattice field theory

Field theory is an "untamed beauty"

Regularisation methods:

1. At high energies only;
2. At all energies: turn the space-time into a lattice.



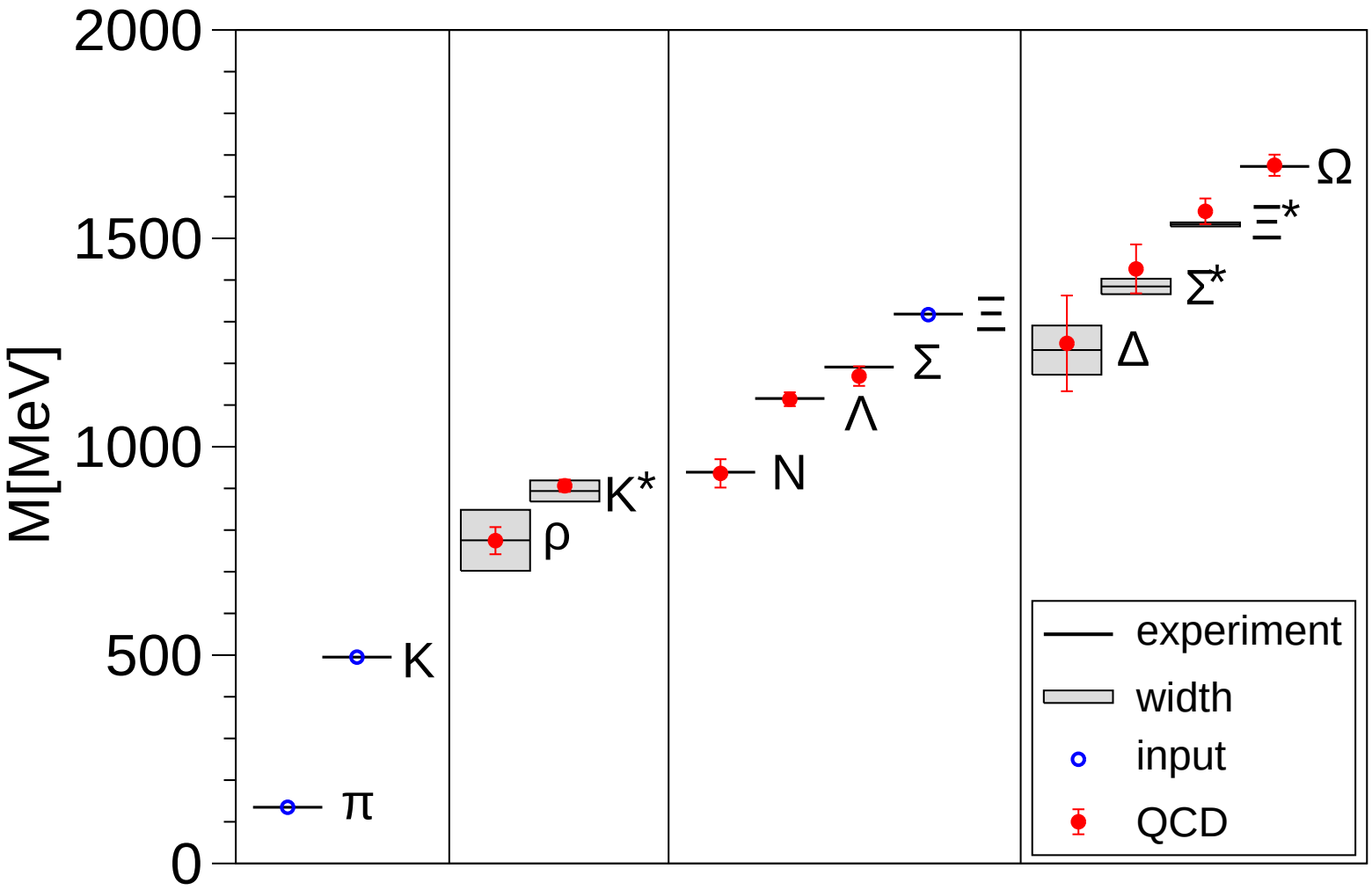
Lattice gauge theory established by Wilson, Kogut-Susskind, Creutz etc., 1974

Calculations:

Analytical: at low energies only;

Numerical: at all energies

Hadron spectrum from lattice computations

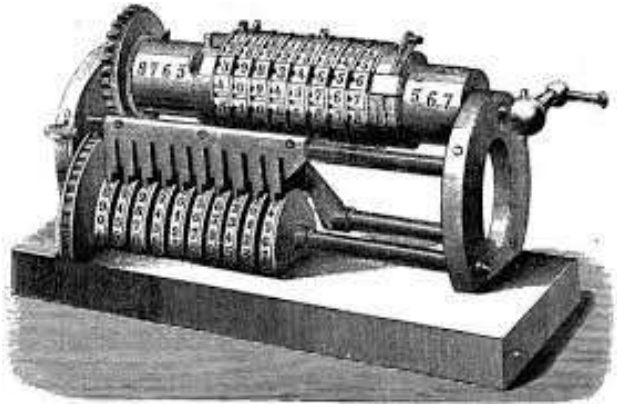


S. Dürr *et. al.*, Science 322:1224-1227,2008

Machinery of lattice gauge theory

What we need?

1. Lattice theories:
   - with all symmetries of the continuum theory but rotational;
   - which are closer to the continuum counterpart.
2. Computing machines:

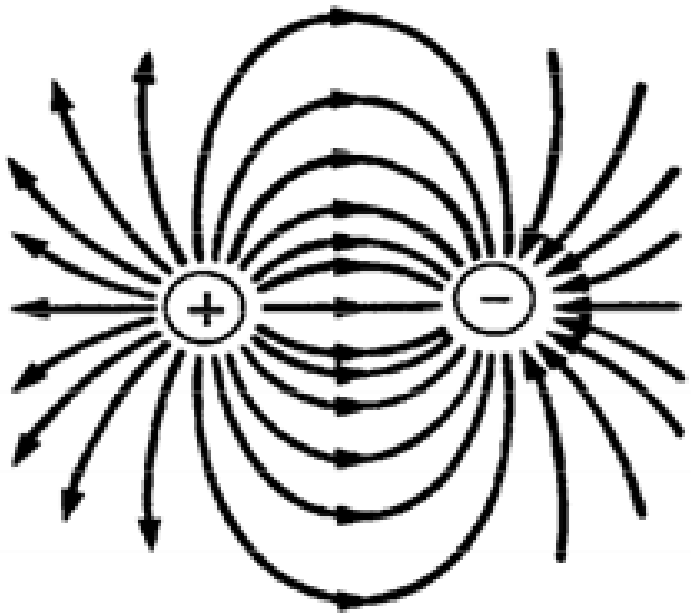


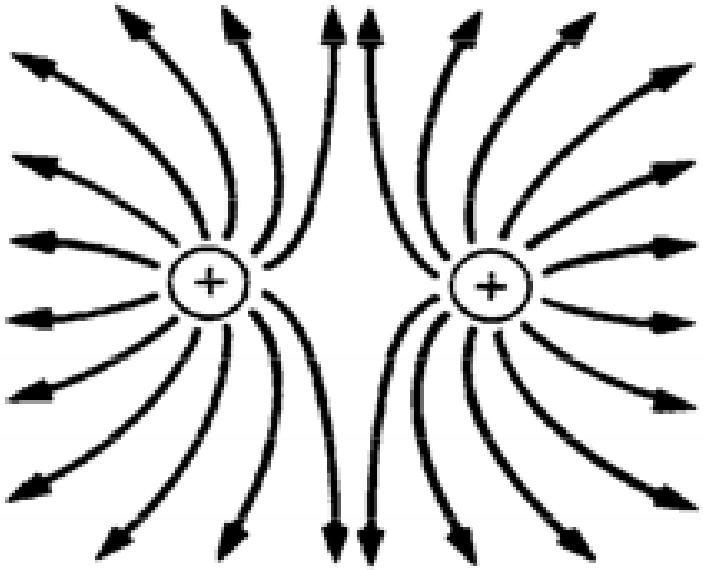
or

- Learn how to use, programme and build them;
- Learn and invent numerical algorithms for lattice field theory.

Interaction of colorless charges

Interaction of two electric charged particles

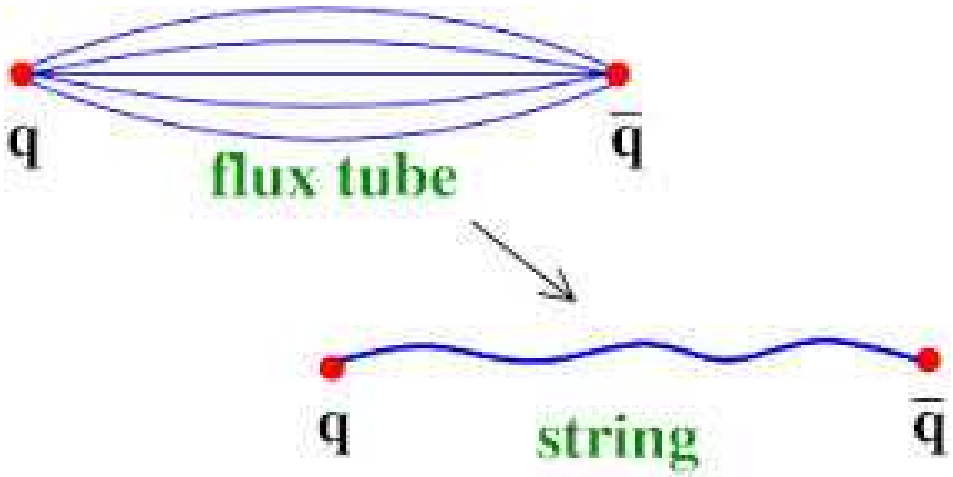




$$V(R) \sim \frac{1}{R}$$

Interaction of color charges: QCD string

Interaction of quar-antiquark pair

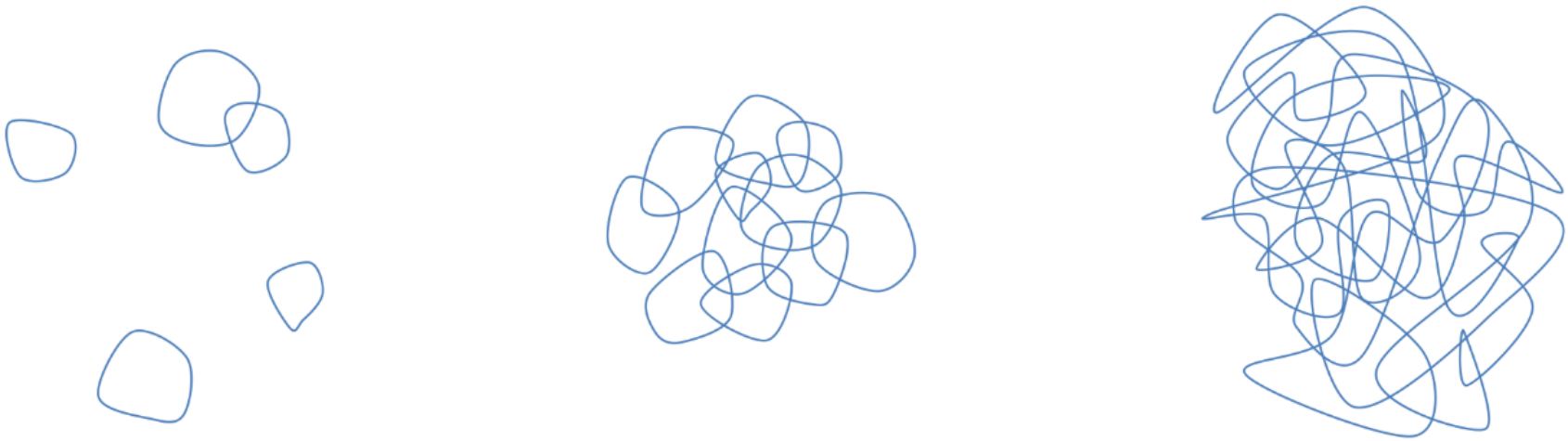


$$V(R) \sim R$$

QCD string at high temperatures: black holes

Low temperatures

High Temperatures



Black holes as long and winding strings

Gravitation as entropic force

Calculation

- Entropy of the string $\sim$ length of the string;
- $\Rightarrow$ The entropic force $\sim$ temperature;
- Temperature $\sim$ mass of the black hole/number of degrees of freedom;
- Holographic principle: number of degrees of freedom $\sim$ area of the black hole;
- $\Rightarrow$ Force $\sim$ mass of the black hole/length of the string squared.

$\Rightarrow$

Newton's law of gravitation

Discussion

Leonard Susskind recent work (2014) offers the picture of:

- Hadron phase of short QCD strings at low temperatures;
- Deconfinement or black hole phase at high temperatures.

Erik Verlinde derives Newton's law of gravitation using:

- The hypothesis that entropy $\sim$ to the position change of an object;
- The entropic force.

We have shown that Verlinde's hypothesis can by derived using:

- The hypothesis that black holes *are long and winding QCD strings*.

Is physics ruled by color?