International Particle Physics Outreach Group

Working group
EXPLAINING PARTICLE PHYSICS to the PUBLIC
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We enter the Scalar Era

Physics for 500 years deals with forces. Forces like Newton's gravity or electromagnetism are represented by **vector fields** pointing from one point to another. Vectors are described by three coordinates at each space point.

Scalar fields are much simpler. They represent just one number per space point. As can be seen from the figures, weather forecasts, for example, contain the scalar fields of temperature, humidity, and pressure. They are not fundamental, however, since they emerge from averaging over the microscopic properties of the air molecules. Wind maps contain vectors but are not fundamental either.

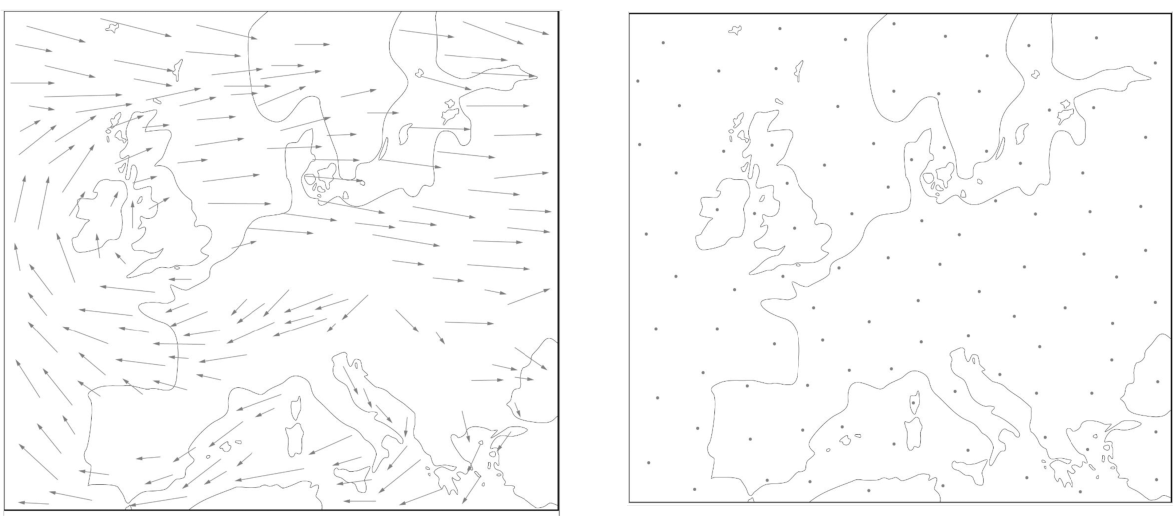

Fig. 1) Representation of vector fields (left) and scalar fields (right).

For the first time in the history of physics we go from studying fundamental vector fields of forces to fundamental **scalar** fields which do not mediate forces. They are omnipresent background fields which fill up the vacuum in the Universe.

Such fundamental scalar fields are:

The **Higgs field**. In the Standard Model of particle physics it gives mass to the fundamental particles. The famous Higgs boson discovered at CERN in 2012 is an excitation of this field and completed the standard model.

The **inflation field.** It is believed to have caused the accelerated expansion of the Universe at the very start of the Big Bang. It may help us to understand what triggered the Big Bang and how its subsequent huge inflation happened.

The **Dark Energy** or cosmological constant. This is also a mysterious new field which dominates the energy content of the Universe. It causes its accelerated expansion and ultimate fate. It is considered to be constant in space and time.

Some physicists argue that all these scalar fields are somehow connected with each other. That is why the understanding of the nature of the Higgs field and of scalar fields in general is crucial to understand the past, present and future of the Universe. It is one of the most burning questions of fundamental science in the 21st century.

Concerning the Higgs particle the most important open questions are:

- The strengths of all fundamental interactions do not depend on the interacting particles. However, the strengths of the interactions of the Higgs field with the fundamental particles vary proportional to the masses of the particles.
  In order to understand how the Higgs mechanism generates these masses we have to test this relation as precisely and for as many different particle masses as possible.

- Check whether the Higgs particle is an elementary or composite particle!

- Check whether there are more types of Higgs bosons (e.g. charged) as predicted by extensions of the standard model.

- Check the stability of our Universe by measuring the masses of the Higgs boson and of the top quark as precisely as possible.
  Specify the Higgs field by measuring the interactions between Higgs bosons!

- The mass of the Higgs boson is not predicted by the standard model of particle physics. Extensions of the standard model explaining its observed low value should be investigated.

The best device to investigate all these important open questions would be a new powerful electron-positron collider serving as a Higgs factory.

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