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Closing Remarks

International School of Subnuclear Physics,
“FROM GRAVITATIONAL WAVES TO QED, QFD AND QCD”,
“Ettore Majorana” Foundation and Centre for Scientific Culture,
Erice, Sicily, Italy,
June 2018
The 20th century stands out as 

*the Century of Science and technology*

physics, astronomy, biology, chemistry, nanoscience, information technology, air travel, space travel, medicine, etc.

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This century is not doing as well as the previous . . . !
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Painful lesson from the history of science: more scientists and larger budgets do not always guarantee faster progress.

Scientists often tend to **stick to procedures and approaches that once have been successful in the past.** For instance:
It was observed that the Standard Model is based on mathematical methods where *symmetry features* (local as well as global) are central. One therefore concludes that all future progress will be based on symmetries.

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What seems “beustiful” for one generation, may look old-fashioned to the next.

This is *not* to argue that we should no longer use symmetry arguments as important leads towards new theories, but simply that they should not always get priority.
When attempting to reconcile the weak force with electromagnetism, we ended up with a theory where the weak force and electromagnetism were “unified”. This was followed by vigorous attempts also to unify this structure, now called ‘electro-weak’, with the strong force, based on $SU(3)$.

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But point # 1: the electroweak theory is not a true unification (It is still composed of a $U(1)$ group and $SU(2)$, with two coupling parameters $g_1$ and $g_2$). It is rather an (interesting) mixture between $U(1)$ and $SU(2)$.

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In the quest for true “Grand Unification”, one searches for a large gauge group with only one coupling parameter.

Fine, let’s try it.
One notes that the Grand Unified group $SO(10)$ works somewhat better than $SU(5)$. I think that the argument that

*the three fermionic representations are all a spinorial representation of $SO(10)$, while they are already a spinorial representation of $SO(3,1)$,*

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**Conclusion:** use symmetries, if appropriate, but do not overestimate their importance. This could be wrong.
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I frequently emphasized that, when ordinary, accepted physical laws are applied to quantum black holes, one may run into self-contradictory predictions.

The source of the difficulty: Quantum gravity is not renormalizable.
Now all we need to ask for is a theory that gives black holes properties that are meaningful and unambiguous.

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And we do hit upon new clues.

But their implications are yet to be investigated.
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How to formulate the Schrödinger equation, if you want a theory with a given classical limit; how it relates to observed phenomena (Born’s probabilities); how the outcome of measurements are to be understood (collapse wave function).

But then they concluded that there are questions one should not ask: what is the reality behind Quantum Mechanics? Or what can we say about that reality?
Not asking questions is bad logic!

Perhaps one should turn questions around (often leads to surprises):

- Are there questions in classical physics, for which Quantum Mechanics methods are known to be the answer?
  - Yes, there are!
    - Onsager's solution to the Ising problem, 1944.

Quantum Mechanics is the theory you get if you don’t know the initial state (because you cannot), and therefore, you can’t know for certain the final state (it appears as a superposition).

You then discover that, when J.S. Bell formulated his famous theorem about Quantum Mechanics, he did not use the correct formulation of causality. The only correct formulation is the one used in QFT (commutators of operators that are space-like separated, must vanish).
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This may be the reason why our progress is slowing down.
THE END