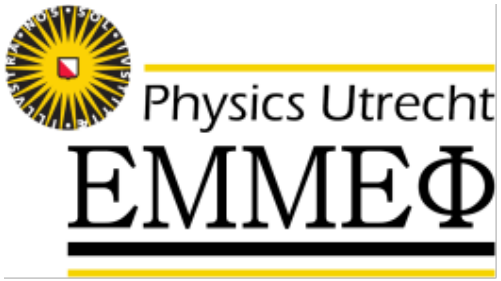
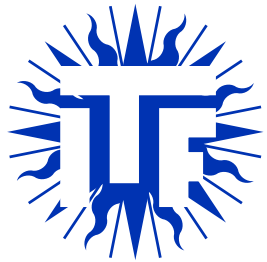




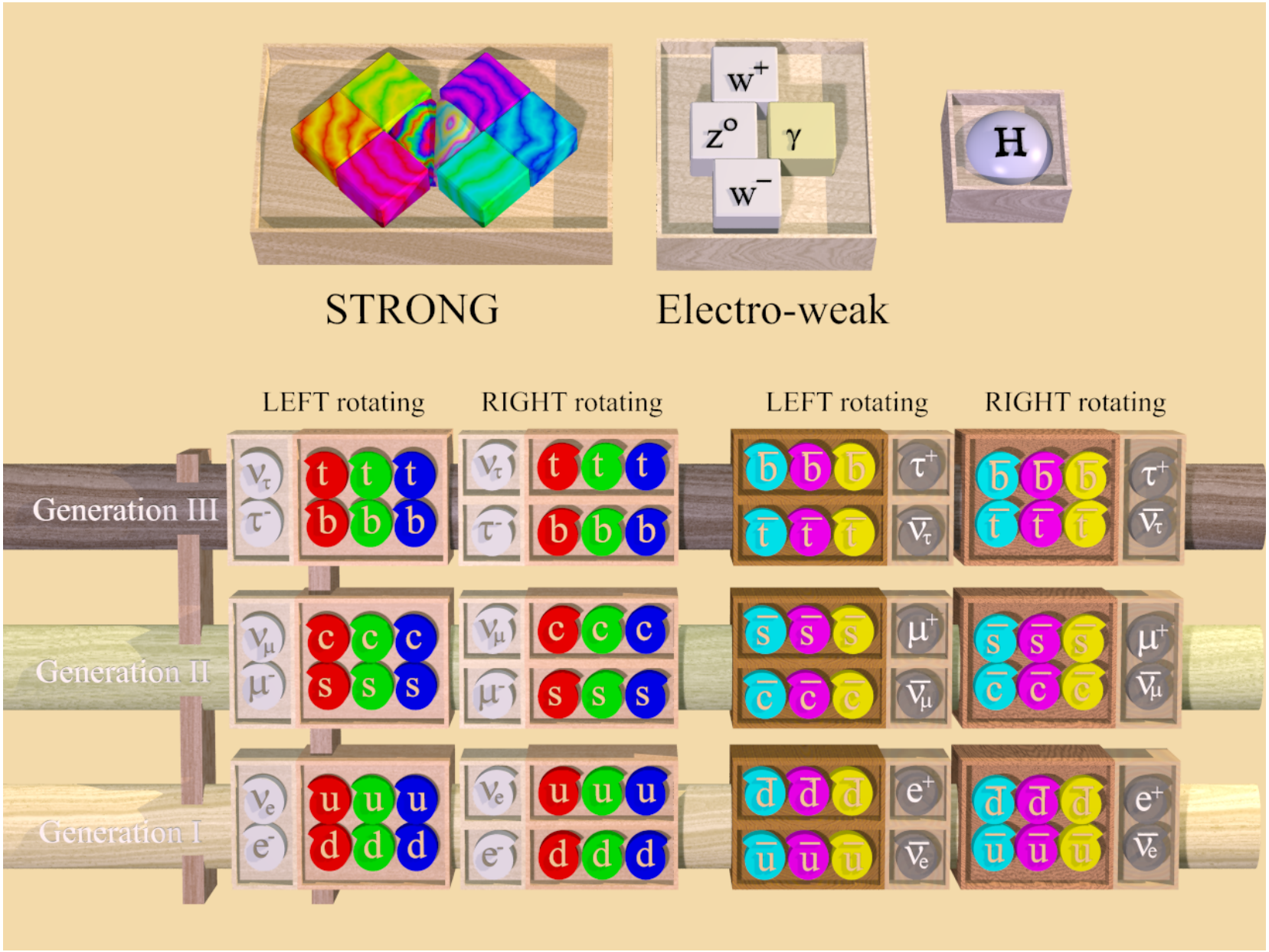
Gerard 't Hooft

Is science in a crisis?

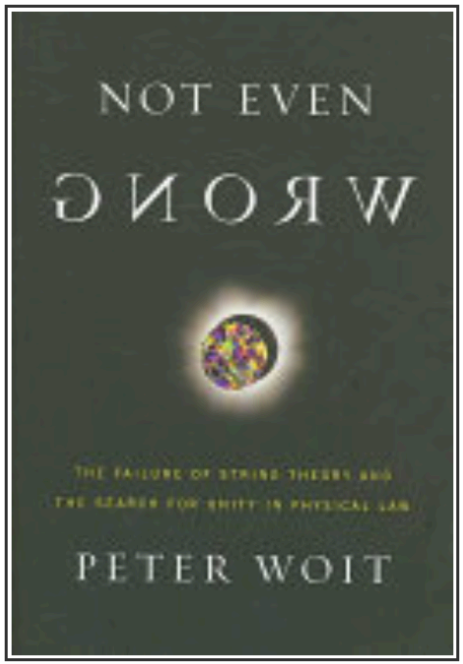
International Symposium
"60 Years of Subnuclear Physics in Bologna"

Centre for Extreme Matter and Emergent Phenomena,
Science Faculty, Utrecht University,
POBox 80.089, 3508 TB, Utrecht

Bologna Academy of Sciences,
and the Italian Physical Society (SIF)
Wednesday, 7 November, 2018

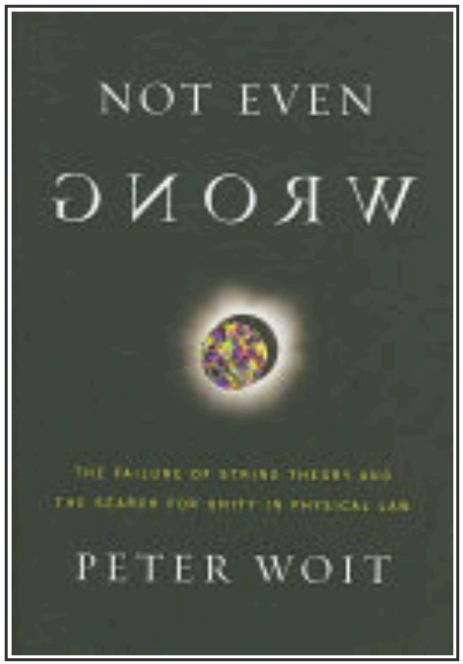


The Standard Model, an overwhelming success of 20$^{\text{th}}$century science



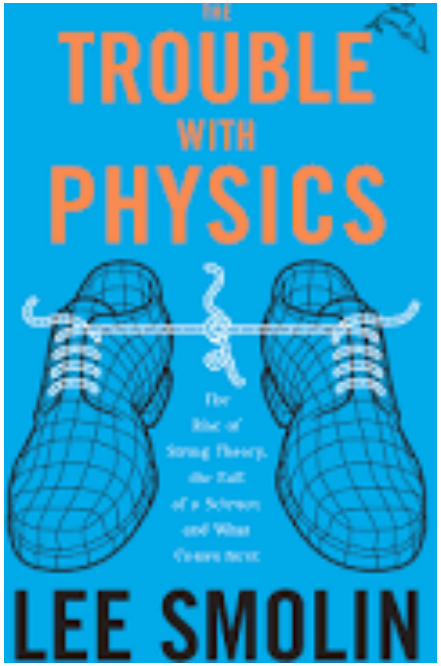
Peter Woit:
Not even Wrong
(2006)

The Failure of String Theory and the Search for Unity in Physical Law



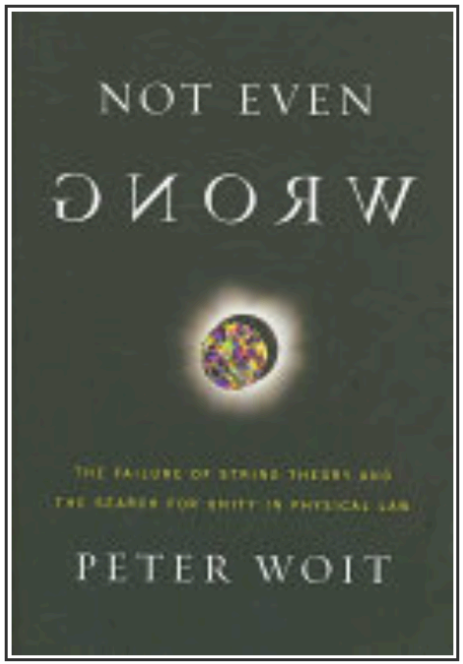
Peter Woit:
Not even Wrong (2006)

The Failure of String Theory and the Search for Unity in Physical Law



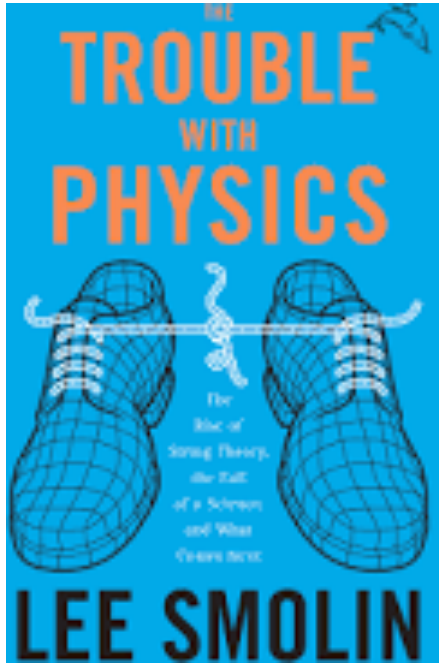
Lee Smolin:
The Trouble with Physics (2006)

The Rise of String Theory, the Fall of a Science, and What Comes Next



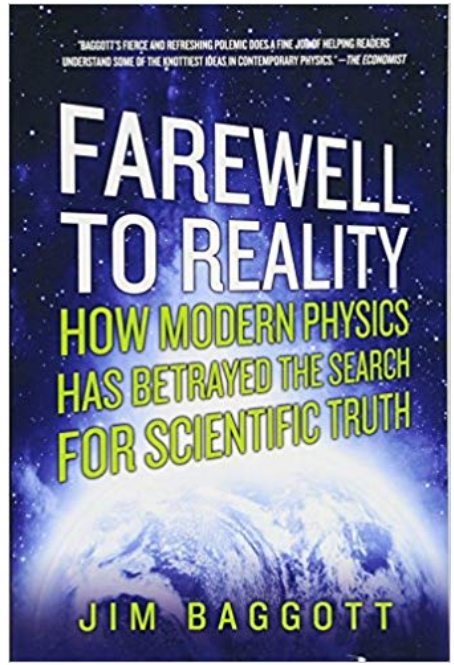
Peter Woit:
Not even Wrong (2006)

The Failure of String Theory and the Search for Unity in Physical Law



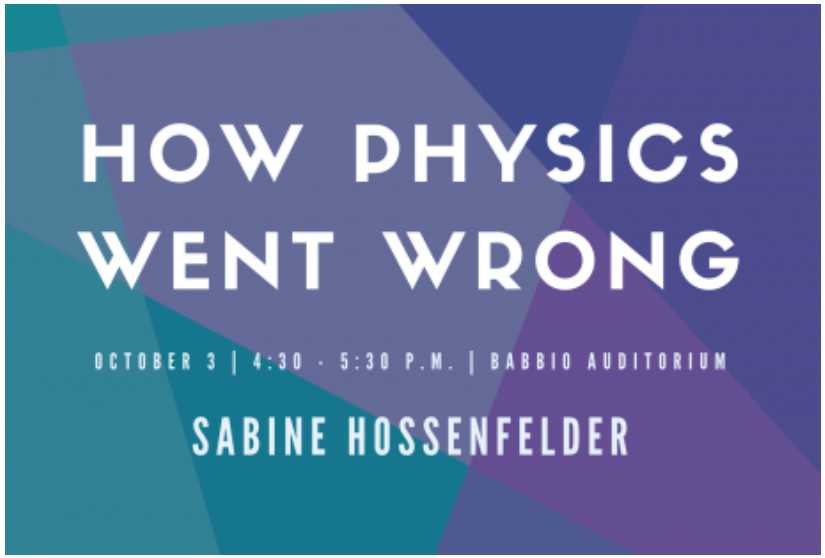
Lee Smolin:
The Trouble with Physics (2006)

The Rise of String Theory, the Fall of a Science, and What Comes Next



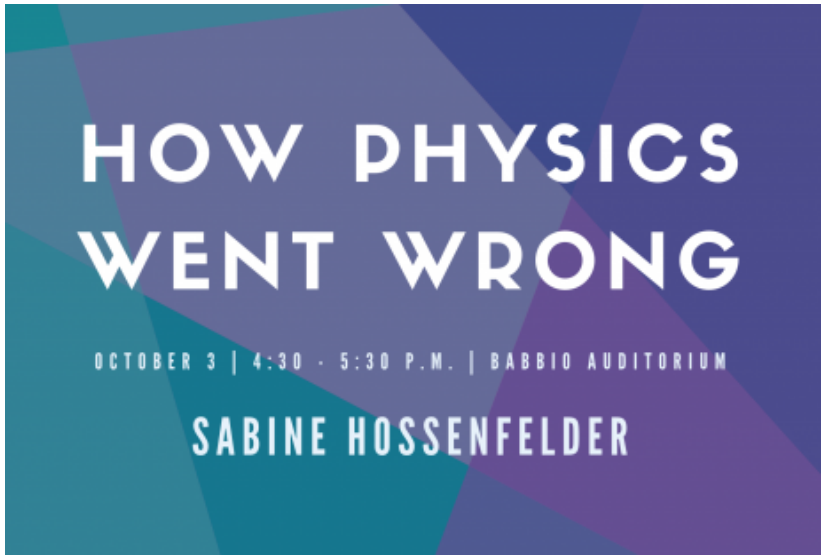
Jim Baggott:
Farewell to Reality (2013)

How Modern Physics Has Betrayed the Search for Scientific Truth



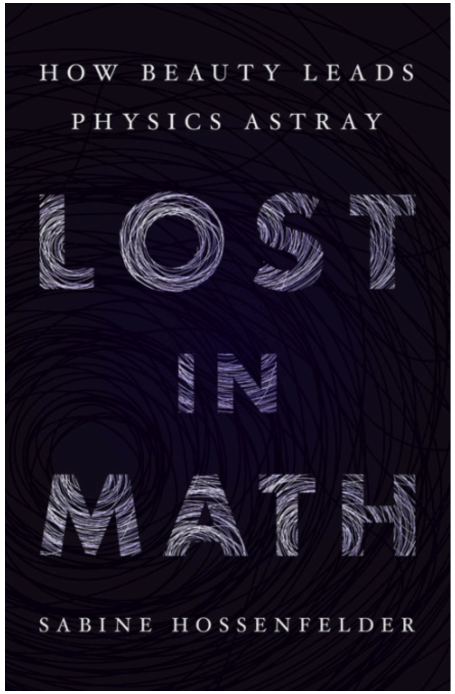
Sabine Hossenfelder,
How physics went wrong
(blog)

The belief in beauty has become so dogmatic, Hossenfelder argues, that it now conflicts with scientific objectivity.



Sabine Hossenfelder,
How physics went wrong
(blog)

The belief in beauty has become so dogmatic, Hossenfelder argues, that it now conflicts with scientific objectivity.



S. Hossenfelder,

Lost in Math: How Beauty Leads Physics Astray

"modern physicists obsession with beauty has given us wonderful math but bad science"

N.G. van Kampen (1921 - 2013)

"The history books in the future will teach us:
The scientific period lasted from 1500 to 2000

N.G. van Kampen (1921 - 2013)

"The history books in the future will teach us:
The scientific period lasted from 1500 to 2000

In the 20^{th} century alone, science made more progress than the millennium before.

Will the 21^{st} century match that?

Or, *Is science in a crisis?*

The years 1900 - 1918:

1900 The energy quanta of light (later to be called photons)
1905 The existence of atoms (from Brownian motion),
the quanta of matter.
1905 Special relativity
1915 General Relativity
Soon to be followed by: Quantum mechanics, nuclear physics, Dirac equation, elementary particles, superconductivity, spectacular technologies: TV, computers, etc.

And now?

The years 1900 - 1918:

1900 The energy quanta of light (later to be called photons)
1905 The existence of atoms (from Brownian motion),
the quanta of matter.
1905 Special relativity
1915 General Relativity
Soon to be followed by: Quantum mechanics, nuclear physics, Dirac equation, elementary particles, superconductivity, spectacular technologies: TV, computers, etc.

And now?

Exoplanets (great technology!), the rise of cosmology,
2011 The Higgs particle (long predicted)
2013 Gravity waves (no big surprise)
Smart phones? autonomous cars? Artficial intelligence?

Today, we hear more complaints:

"Students, young scientists, postdocs, are meekly following their teachers and peers",

"while today's most significant theories seem to be disconnected from any possibility of experimental checks."

"There seems to be little real progress taking place today. Especially in particle physics."

However, remember:

In a slightly more distant past, progress in science was also slow:

Isaac Newton, *Principia*, 1687 ;
James Clerk Maxwell, 1865, nearly 2 centuries later .

Perhaps the 20^{th} century was an anomaly.?

In a slightly more distant past, progress in science was also slow:

Isaac Newton, *Principia*, 1687 ;
James Clerk Maxwell, 1865, nearly 2 centuries later .

Perhaps the 20^{th} century was an anomaly.?
The natural progress in science has always been much slower than in the 20^{th} century.

During the 20^{th} century, investigators realised the tremendous shortcomings of existing lore, dating back from antiquity, and whereever they went, whatever they investigated, new approaches were discovered and found useful.

Today, we are still heavily dependent on approach philosophies that were introduced more than 100 years ago.

Today, it is not yet realized that what made sense 100 years ago, could be refreshed and adapted, so as to face today's problems.

In physics, new obstacles have come along, that require new ways of thinking:

Examples:

Today, it is not yet realized that what made sense 100 years ago, could be refreshed and adapted, so as to face today's problems.

In physics, new obstacles have come along, that require new ways of thinking:

Examples:

1) String theory: in the past, theoretical ideas could always be subject to experimental tests. It was relatively easy to select viable arguments from dead alleys. Once you had a good idea, you could test it using "toy models".
   Now, leads of this kind are lacking. Toy models are still being investigated, but their theoretical foundations are lacking.
   To really make progress, internal, logical accuracy is much more important than ever before. It is lacking in our toys.

2) Quantum mechanics. Dogmatic approaches convinced investigators that "hidden variables" are not the way. They do not see the analogy with bygone years, when quantized field theories (QFT) were being dismissed. The logic in these arguments contains demonstrable flaws.

   The idea of extreme and absolute rigor in Nature's laws is not yet embraced; we are still allowing for magic and mystisicm, even in the most modern theories. This is severely hampering progress.

Note: this is a personal view of mine. Not everyone agrees with it.

I am merely suspecting that irrational conservatism is holding us back today.

Imagine a biologist investigating intelligence of rats. Rats are held in a large cage, full of gadgets. These gadgets are intelligence tests. By pulling strings, pressing buttons, moving handles and switches, the rats can get access to food that tastes a lot better than what they normally get. They can see how the strings, the switches, buttons and handles work. By logical deduction, they can obtain the food they want.

The rats know that they succeeded many times in the past.

Now, they see a delicious peanut, which should be obtainable if you think right. Unfortunately, the test is too hard. The rats know that they are too stupid. This time, none of them succeeds in getting hold of the delicacy.

We humans feel just like these rats. We are lacking the intelligence needed to quantise gravity. We have to improve our logic.

Is science in a crisis? **NO !**

If you think so, you're forgetting that:
Breakthroughs are often not immediately recognised as such.

1) Ludwig Boltzmann got depressed when he thought his work was not being noticed. His work is now recognised as a breakthrough, but only after his death.

   We are making breakthroughs today, but most of us are not aware.

Is science in a crisis? **NO !**

If you think so, you're forgetting that:
Breakthroughs are often not immediately recognised as such.

1) Ludwig Boltzmann got depressed when he thought his work was not being noticed. His work is now recognised as a breakthrough, but only after his death.

   We are making breakthroughs today, but most of us are not aware.

2) 21^{st} century science differs from the 20^{th}. Now, only the exceptionally difficult problems are left over. It will take longer to unravel these. Eventually, *AI* will be able to solve our excessively hard physics problems:

- What can cosmology *really* tell us about the origin of the universe (BB1), and physics beyond the Planck scale?
- What will be needed to quantise gravity?
- What role will ('quantum') black holes play?
- Which principles should be applied in solid state physics to obtain room temperature superconductivity?
- How do biological organisms respond to the DNA code?
- What are the laws for complex organic molecules?
- What do we need technically for the colonisation of outer space?

Maybe, artificial intelligence (*A.I.*) will not be able to surpass – or even compete with – human intelligence.

But, one can also consider / hope for more elevated expectations for the (near) future of A.I.

To see, and compare, the new breakthroughs, one must realise that science hotspots are continuously moving around:

Atomic physics (spectral lines) $\rightarrow$
nuclear physics $\rightarrow$
subnuclear particle physics $\rightarrow$
cosmology and astrophysics (BB1) $\rightarrow$
science of (the origin of) life (BB2) $\rightarrow$
how does the DNA code work $\rightarrow$
foundations of QM and GR $\rightarrow$
artificial intelligence (BB3), etc.

If you aren't prepared to move together with the new trends, you will think that science is in a crisis.

The crises aren't in science, but in the minds of immobile scientists, who are disappointed by the non-linearity of progress ...

AND

If you aren't prepared to move together with the new trends, you will think that science is in a crisis.

The crises aren't in science, but in the minds of immobile scientists, who are disappointed by the non-linearity of progress ...

AND

The 21^{st} century is not over yet.

Thank you