Five Revolutionary Ideas in 1950s-70s Science: 90th Birthday of Revolt Pimenov

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Abstract

This year, Revolt Pimenov, a philosophical thinker whose main ideas were in geometry of space-time, would have turned 90. In this essay, we explain how in the 1950s-70s, when he was most productive, his were two of the five natural and important revolutionary scientific ideas – along with fuzzy logic, constructive mathematics, and scalar-tensor theory of gravitation, ideas that, in our opinions, still have potential to change the world.

1 Why Does Science Need Revolutionary Ideas

Revolutions in general: pro and contra. People have different attitudes towards revolutions.

On the one hand, revolutions often overthrow oppressors, bring hope, make many people happier. In many countries – in France, in the US – anniversary of a revolution is a major national holiday.

On the other hand, revolutions bring sufferings, civil wars, deaths – and often, bring new oppressors who sometimes become even more brutal than the previously overthrown ones.

So what is a revolution in science? In countries where revolution is a good idea, this word is used to praise – to make people enthusiastic about a new scientific theory, new research result, journalists writing about science call it a revolution. For this reason, journalists use this word even when there is a tiny step forward.

On the other hand, in countries where the word "revolution" had many negative connotations, journalists are reluctant to apply this word to scientific ideas – even when these ideas drastically change the scientific landscape.

These over-eagerness or reluctance to use this word does not change the fact that some ideas propose drastic changes – are, in other words, *revolutionary* ideas, while other ideas lead to gradual, *evolutionary* improvement. This is how we will understand the word "revolution" in this paper.

Comment. We decided not to hide behind synonyms like paradigm shift. We do not want to allow bad guys affect our linguistic decisions. It is well known that bad guys demagogically use many good words to do bad things, from burning people alive in the name of loving your neighbor as yourself to 20th century nightmarish dictatorships packaged in good words and seemingly good ideas like equality and happiness.

Why do we need revolutions in science? Why cannot science evolve gradually – as it often does? The answer to this question is clear to anyone who ever tried to find a solution to an optimization problem: if we only perform local optimization (e.g., gradient techniques), we usually end up in a local maximum. To find the true (global) maximum of an objective function, we need to make a drastic move out of the local optimum.

Similarly, in science, gradual evolution often leads us to a local optimum – we are not yet predicting physical processes perfectly accurately, but we have reached (or almost reached) the limits of what the gradual changes can do. No gradual change will allow us to make a significant improvement. For this, we need a drastic change – i.e., a revolutionary idea.

2 What Happened in 1950s-70s

What science is about: a brief reminder. Among the main goals of science is to *describe* the current state of the world and to *predict* the world's future state.

Let us recall how both goals are usually pursued.

How was (and often is) the word described. To get a better understanding of the world, we measure the values of different quantities. Thus, the state of the world is usually described in terms of the values of different quantities; see, e.g., [8, 18].

Some of these quantities can take all possible values, some only take values from some discrete set. Until the 20 century, this distinction was very clear. In some cases, we have "yes"-"no" properties: alive and not alive, etc., i.e., in effect, discrete variables. In other cases, we have a continuous quantity like energy, charge, mass, etc., that can take all possible values.

Early 20 century physics changed this description. Special relativity made it clear that for some quantities, some values are not possible: e.g., velocity cannot exceed the speed of light. Quantum physics showed that some quantities can only take values from a discrete set – e.g., electric change, or an energy level of an atom.

Still, what was previously discrete ("yes"-"no") remained discrete.

First revolutionary idea: fuzzy logic. While the idea of "yes"-"no" questions is natural in science, in real life, such questions are rare. In most cases, we do not have strict "yes"-"no" distinctions between young and old, healthy and sick, short and tall, etc. Even in seemingly simple situations like alive-not alive, there is sometimes no strict border: is a virus alive? is a brain-dead person alive?

In view of this, Lotfi Zadeh suggested that it would be reasonable to follow the same pattern in science as well – and to claim that everything is a matter of degree. This idea led to many useful practical applications, especially in designing efficient controllers for trains, elevators, cars, video cameras, washing machines, rice cookers, etc.; see, e.g., [3, 9, 12, 14, 15, 20].

Second revolutionary idea: enter Pimenov. An even more radical idea was proposed by Revolt Pimenov. Let us briefly describe this idea.

In our life, we have measuring instruments, so we can get numerical values of different quantities. Clearly, in extreme conditions, our measuring instruments will not work, maybe none of the instruments will work. In a very strong gravitational field, all instruments will be torn apart. Near the Big Bang, there were clearly no measuring instruments. In the micro-world, the uncertainty principle prevents us from making meaningful measurements.

The existing physical paradigm understand this very well, but still continues to describe the world by numerical quantities, even when there is no way to actually measure these quantities. The only reason for using these quantities is that the physics equations are written in terms of numerical quantities – but, honestly, from the physics viewpoint, this is not a very convincing argument.

Pimenov's main idea was: since we cannot measure these quantities, why describe them? Let us allow the areas of the world – be it on cosmological level or on the micro-level – where we do not have any numerical characteristics. But what *do* we have? Well, for example, we have the notion of causality: some events cause other events. Motivated by this idea, he started studying physical models – models of space-time with events in it – in which the only structure we have is the causality relation. He called such models *kinematic spaces*; see, e.g., [16].

This is still a rather radical idea, but it is already part of mainstream physics: e.g., already in 1973, the idea of "foam" space-time where numerical quantities make no sense, was included into an encyclopedic textbook on gravitation theory [13].

How the state of the world changes: description before the 1950s-70s revolution. So far, we talked about how we describe the state of the world. But this description only starts the scientific process. The most important thing is to predict the future state, i.e., to predict how the state of world will change.

Before the late 1950s, the description of such changes was straightforward:

- some physical quantities do not change, they are what is called fundamental constants: Planck's constant, speed of light, gravitational constant, etc.;
- other quantities change according to differential equations; and

- by using these equations, we can, in principle, reconstruct the future state.

In the 1950s-70s, all these three ideas got challenged.

Third revolutionary idea: "constants" may change. Many things that we originally thought to be constant turned to be changing. For example, the free fall acceleration of 9.81 m/sec^2 turned out to be slightly different in different locations – and by measuring this acceleration, we can get a lot of information about the density of the material below the Earth's surface.

So, a natural idea is to believe what we now consider to be constants will turn out to be changing – i.e., will turn out to be a new (scalar) physical field. This idea first originated in gravity, since gravity is a relatively weak force, and thus, the accuracy of determining its constant is much lower than of other fundamental constants. The result was scalar-tensor theory of gravitation, first proposed by Brans and Dicke. This theory also became mainstream [13] – and it started an avalanche of other theories in which fundamental constants are changing.

For example, a recent discovery of the Higgs boson confirmed that rest masses of elementary particles – which were previously assumed to be fundamental constants – are actually due to the Higgs field.

Fourth revolutionary idea: non-smoothness. Many observed processes are non-smooth, even discontinuous: phrase transitions, explosions, etc. So why should we insist that processes in nature be smooth? Just because Newton succeeded in describing planetary motions by differential equations does not necessarily mean that all the processes should be smooth. And indeed, e.g., many large-scale gravitational phenomena: the Big Bang, the black holes – show some degree of non-smoothness.

This motivated Pimenov to consider space-times which do not necessarily have the usual smooth structure, space-time models which are not smooth [16].

Fifth revolutionary idea: maybe not everything is computably predictable. While we can predict the motion of planets hundreds years into the future, from the commonsense viewpoint, it is not realistic to expect that we can predict our own actions and thoughts – although, strictly speaking, our actions and thoughts are also described by some differential equations. So why not abandon the naive belief that everything can be predicted and learn to distinguish between situations in which predictions are possible and situations in which predictions are not algorithmically possible.

A natural way to do it is to introduce, in addition to usual existential quantifier – which simply means that the object with given properties exists, not necessarily that we can compute it – a special "constructive" quantifier, whose meaning is that there is an algorithm for computing the desired object. This, in a nutshell, is the main idea behind what was called *constructive mathematics*; see, e.g., [1, 2, 4, 5, 6, 7, 10, 11, 17, 19].

In some sense, this is also now part of the mainstream: maybe not necessarily in the original logical terms, but definitely computational questions are an important topic in mathematics, especially in applied mathematics.

Summarizing. For science to progress, it is not sufficient to have evolution: we need revolutionary steps, steps leading to drastic changes. In the 1950s-70s, several such changes have indeed been proposed, changes that are now largely part of the mainstream science. And of the pioneers who introduced these changes was Revolt Pimenov.

Acknowledgments

This work was supported in part by the National Science Foundation grants 1623190 (A Model of Change for Preparing a New Generation for Professional Practice in Computer Science), and HRD-1834620 and HRD-2034030 (CAHSI Includes).

It was also supported by the program of the development of the Scientific-Educational Mathematical Center of Volga Federal District No. 075-02-2020-1478.

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