

PHYSICS, MATHEMATICS AND COSMOLOGY*

By

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Summary

*Realistic Cosmology is neither simply Mathematics, nor simply impressive photographs, nor simply a powerful electronic computer, nor a particle accelerator but, beyond and above all these, firstly and mainly, it is physical thought, physical way of thinking, physical intuition, physical realism, namely and in short, it is **Physics!***

Physics, Mathematics and Cosmology

Dear Attendees,

For the invitation to give this lecture, I wish to express my sincere thanks to *Dr Kostas Vourlias*, to the hosting *Thessaloniki American Farm School*, and to all the organizers and co-organizers of the “*First Balkan Student Summer School on Astronomy and Astrophysics-A child from the Balkans counts the stars*”, the main objective of which is to promote the idea of teaching cutting edge *Physics* and *Astronomy* in Balkan schools.

The purpose of this, *comparatively short, closing lecture* is to offer to you, *the younger generation*, some interesting and useful messages, concerning the appropriate method for study and research, particularly in *Cosmology*, and, more generally, in *Astronomy* and in *Astrophysics*.

And, for such a purpose, you, the younger generation, are the appropriate audience.

I shall not show you **any** mathematical relations, or detailed tables, or composite figures, mostly unnecessary. Only some very simple and easily understood slides will be shown.

Notice that, for the interested of you, my lecture will soon be available through my electronic address **spyrou@auth.gr**

However, I wish to kindly ask you to pay attention to the *useful message* I want to pass to you, particularly to those of you, possibly, interested in future research work in the broad astronomical-cosmological area. And this useful message refers to the way *physics* and *mathematics*, as two entirely different areas of knowledge, should be used in a *realistic* description of the cosmological Universe, namely, a description that is also physically oriented, not only mathematically oriented.

This message is closely related to a very useful personal experience of mine since the early 1970s, the time of my doctoral thesis. As the late Professor *Sir William Hunter*

McCrea (1904-1999) said in his Presidential Address to the Royal Astronomical Society,

*“I am always surprised when a young man tells me he **wants to work** at cosmology.*

*I think of cosmology as something that **happens to one**, not something one can choose”.*

In other words, working with Cosmology is not something to choose between other possible choices. Working with Cosmology is something “*coming from your inside*”, and it is not possible to abandon Cosmology, even if (for many reasons) you are forced to do so. This is the case with the present speaker, who started his research with Cosmology and, after making a scientifically necessary, useful and productive tour to many other astronomical research areas, he returned to Cosmology.

Beyond this truth, it is very useful and helpful, in your interactions with other scientists, to remember also the following two truths:

“If you can’t explain it simply, you don’t understand it well” (by *Albert Einstein*), and the equally important

“The greatest enemy of knowledge is not ignorance, it is the illusion of knowledge” (by *Stephen Hawking*).

After these introductory and informative remarks, *Cosmology*, as you most probably know, is the science aiming at the study of the Universe as a whole, its *beginning*, its *evolution* and its *possible end*.

The study of *Cosmology*, as of every other physical scientific area, is based on the mutual interaction between theory and observations/experiment.

Suppose that we wish to study the dynamic behavior of a physical system. This system can be, e.g., the atmosphere of the Earth, or a star and its evolution, or a galaxy and its properties, or a system of galaxies, or, even, the Universe as a whole.

In the dynamical description of each one of these physical systems, in simple words, we use an underlying,

well-established theory, that makes certain theoretical predictions.

In Cosmology, this theory is Einstein's *General Relativity Theory (GRT)*.

Now, the predictions of the theory used are *either verified or disproved* by the experimental or/and observational results. If a theoretical prediction is verified, the theory is enhanced and proceeds to another theoretical prediction, and another one, and so on, *with this procedure being applied to all (not only one or a few!)* of the available experimental or/and observational data.

But, even if only one theoretical prediction does not agree with the experimental or/and observational results, then the whole theory collapses, it is rejected and, if possible, it must be improved, as regards, e.g., its main and basic assumptions.

This is and this should be the usual way scientific progress proceeds.

Notice, that, so far, no astronomical-cosmological theoretical prediction of the GRT has been disproved. Up to now, all of them have been verified by observations.

Furthermore, it is obvious that, necessarily, for the research to be realistic and reliable, the theoretical predictions and the corresponding experimental or/and observational data themselves must be *reliable*.

Well, what “*reliable observational data*” means? It means that the presented observational data are not, say so, “*cooked*”, namely, they, truly, express what the observations/experiments have revealed.

But, also, the underlying theory and the corresponding theoretical predictions must be *reliable from both the mathematical point of view and the physical point of view*.

And at exactly this point lies the most serious problem concerning the way cosmological research is done. Namely, *up to now, cosmological research has been only mathematically oriented, but, not, at the same time, also physically oriented*. This necessity is known since long ago, as, Einstein himself had emphasized,

“As far as the laws of mathematics refer to reality, they are not certain, and, as far as they are certain, they do not refer to reality”!

Let me be a little more precise and detailed on this. In describing the Universe as a whole, we have many reasons to assume that, on very large scales, the content of the Universe is in the form of a continuous medium. Not a system of galaxies, each one of linear dimensions small, almost negligible compared to the mutual distances of neighboring galaxies.

This continuous medium, in general, is composed of various forms of mass and of various forms of energy.

The mass, both baryonic and dark, as we all are used to know, is gravitational, namely it creates a field of the familiar *attractive* gravitational forces, which tend to shrink the physical system under consideration.

Also, it is known, that, according to the well-known formula $E=mc,^2$ any amount of energy, E, is dynamically equivalent to a certain amount of mass, m.

Therefore, every form of energy, like mass, creates a gravitational field, and so both mass and energy in the Universe are responsible for the universal gravitational field, producing all the observed motions and phenomena in the Universe.

Consequently, the cosmological continuous medium, dynamically, can be treated as a *continuous gravitational physical system*, in other words as a *gravitational fluid*, and this fluid is called the *cosmic fluid*.

Notice, however, that, until very-very recently, in cosmological research, **all forms of energy of the *cosmic fluid* have been ignored and omitted as sources of the universal gravitational field.** In all the theoretical cosmological treatments and theoretical results, tacitly, all these forms of energy have been omitted and **only the mass** has been taken into account as the source of the universal gravitational field.

Now, what “*taken into account*” means? Well, the dynamical-thermodynamical description of such a gravitational fluid is very well known, and in this context,

the cosmic fluid, is characterized by many physical thermodynamical characteristics, such as (beyond *mass density*) *pressure, temperature of matter, heat quantity, heat capacity, thermodynamic transformations, polytropic transformations, internal thermodynamic motions, internal thermodynamic energy, entropy (as well as other statistical-physics characteristics) et c.*

Furthermore, the relativistic dynamical-thermodynamic description of the cosmic fluid is based on the use of the so-called *Field Equations of the GRT*. The important feature of these equations is that, beyond mathematics (namely, the *tensorial mathematics* used), they contain two important physical parameters of the cosmic fluid, *the thermodynamic pressure, p , and the total mass-energy density, ε .*

At exactly this point lies the above-mentioned problem with the research in Cosmology, and, since long ago, this mostly serious problem, appeared as follows:

About a century ago (1932), two great scientists (*Albert Einstein and Willelm de Sitter*) proposed a solution to the

field equations describing a cosmological model of the Universe, the so-called *Einstein-de Sitter* cosmological model. *This model, however, in accordance with the prevailing cosmological ideas a century ago, is composed only of mass, namely, it has no thermodynamic content at all. In other words, and in physical terms, in the Einstein-de Sitter model, the thermodynamic pressure of the cosmic fluid is zero, its thermodynamic content is totally ignored and, so, quite unphysically, this cosmic fluid is, simply, dust.*

In their two-page long article the two scientists argued “*It seems certain that the pressure p in the actual universe is negligible as compared with the material density $\rho_0 c^2$. The same reasoning, however, holds good if the pressure is not neglected*”.

And, furthermore, they concluded

“*...for the sake of simplicity, we neglect the pressure p ...*”.

These assumptions, a century ago, were not strange and were in accordance with the then prevailing mathematically oriented philosophy in Cosmology. **And they expressed the**

agony of the theoreticians, at last, to find a cosmological model of the Universe!

The strange thing, however, is that, after whole a century, this model, based on the above assumptions, has been in use until very recently. And, especially, the Universe was considered as *dust*, with, however, *not any problematization at all for this and for its consequences*.

I could say that this is like assuming that the air in this beautiful lecture hall is composed of *only particles with mass, nothing else*. Or it is like assuming that the Earth's atmosphere has no pressure (it is dust), and we are not interested in its consequences in the preparation of a reliable weather forecast.

Based on the simple law of *perfect gases*, can you imagine what, really, a vanishing thermodynamic pressure in this lecture hall means? It would mean a vanishing temperature, whence one could ask "*how we remain alive, although frozen at absolute zero?*".

Well, from a physical point of view, it is truly disappointing and curious that, until very-very recently, *really very-very recently, to the above note not any special attention was given at all, especially to the fact that the cosmic fluid had no pressure.*

The consequences of these assumptions are very important and have prevented cosmologists from solving many current cutting-edge cosmological problems.

I shall mention only one, widely known problem, that is related to the *composition of the cosmic fluid*: In the context of the *Einstein-de Sitter Cosmological Model*, among many others, like the vanishing pressure, only the (then known) “*baryonic or luminous matter*”, was known and was taken into account in solving the field equations of GRT.

Later, with the discovery of *dark matter* and given many other observational data, the *Einstein-de Sitter model* took the form of the currently prevailing cosmological model.

Namely, in this prevailing model of *generally vanishing pressure*, 5% of the mass-energy content of the cosmic fluid is our familiar “*baryonic or luminous matter*”, 25% is the so-called and unknown “*dark matter*”, **and the rest 70%, exotic and totally unknown, was given the name “*dark energy*”.**

The dark energy has been denoted by Λ , the unknown *cosmological constant*, and so, it has characterized *the currently prevailing Λ CDM (Λ Cold Dark Matter) Cosmological Model.*

Notice, *that also in the context of the Λ CDM Model*, among many others, 95% of the Universe’s mass-energy content is still unspecified!

And, also, notice that in the *Λ CDM Model*, an unknown, the *cosmological constant*, is used to explain another unknown, the *dark energy*, a, really, absurd situation!

The way *out* of this dead end was revealed, about 13 years ago (in 2011, as Professor Kleidis, in his talk, vividly has described it to you in detail) and only when **all the above**

mentioned physical thermodynamical characteristics of the cosmic fluid had been consistently taken into account as *sources of the universal gravitational field*.

Particularly, the matter, baryonic and dark, is not there standing immovable and frozen, as in the Λ CDM model, but, quite physically, it is characterized by collisions of their moving constituent particles, so that the kinetic energy of these particles is distributed, with, as a result, the Universe to acquire the properties of a continuous thermodynamic medium.

This is the polytropic model with collisions and thermodynamic content, and, in the international bibliography, it is known as the Polytropic Collisional Cold Dark Matter (PC/CDM) Model.

Obviously, the PC/CDM model is a much more physical fluid, but also a much more complex and difficult fluid to treat with (in the sense, also, of the much more *difficult and time-consuming* preparation of original scientific publications!).

In it, the PC/CDM model, however, almost all the current cutting-edge cosmological problems were confronted successfully, in a self-consistent and classical way with the use of only *Classical General Relativity Theory* and *Classical Thermodynamics*.

In other words, neither *quantum theory*, nor *modified gravity* are necessary for the dynamical description of the observationally approachable Universe.

Such problems, **definitely solved in the PC/CDM model**, are, e.g., *the spatial flatness of the Universe, the dark energy (as the thermodynamic internal energy of the polytropic cosmic fluid), the cosmic acceleration, the transition from deceleration to acceleration, the deceleration parameter, the age of the Universe, the cosmological constant, the Hubble Diagram of the distant supernovae, the supernova dimming, the coincidence problem (why the cosmic acceleration happened “now”), etc.*

On all the above, to those of you who are possibly interested, I could give further information and international bibliography. As a first source, however, you can see the quite recent (2023) article

“The dark energy as a natural property of cosmic polytropes - A Tutorial”,
2023, *Review Article*, K. Kleidis and N. K. Spyrou, *Dynamics* 2023, 3(1),
71-95; <https://doi.org/10.3390/dynamics3010006>.

*In Special Issue **Recent Advances in Dynamic Phenomena**,*

Website: <https://www.mdpi.com/2673-8716/3/1/6>

PDF Version: <https://www.mdpi.com/2673-8716/3/1/6/pdf>

with further extended international bibliography in it. Also,
interesting information can be found in the useful site

agapakis.eu

Closing my short talk, I suggest that, in the future, you
consistently remember four things:

The first is what the late Professor McCrea said long
ago. Essentially, working with Cosmology is not something
to choose between other possibilities. It is something
“coming from your inside”, and, even if you are forced to do
so, it is not possible to abandon Cosmology.

The second is that, always, you must have the courage
to say and defend your free and, absolutely and well,
established opinion.

The third is that, according to Einstein, “*As far as the laws of mathematics refer to reality, they are not certain, and, as far as they are certain, they do not refer to reality*”!

And the fourth message I wish you to remember always in your future cosmological research is:

Realistic Cosmology is neither simply *Mathematics*, nor simply *impressive photographs*, nor simply a *powerful electronic computer*, nor a *particle accelerator*, but beyond and above all these, *firstly and mainly*, it is physical thought, physical way of thinking, physical intuition, physical realism, namely and in short, **it is *Physics!!!***

Thank you very much for your attention, patience and insistence!

**N. K. Spyrou,
American Farm School, Thessaloniki,
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