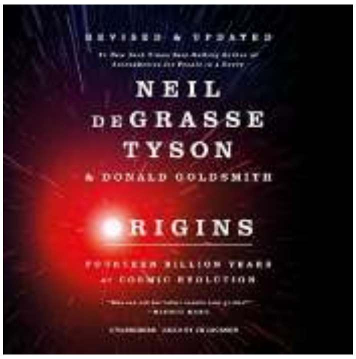


**Origins**
Fourteen Billion Years of Cosmic Evolution
Revised and Updated Neil de Grasse Tyson and
Donald Goldsmith

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*To all those who look up, And to all those who do not yet know why they should*

Neil de Grasse Tyson’s latest book *Origin* starts with a summary of the scientific knowledge of the origin of our world which is founded on the expansion model proposed by Steven Weinberg 20 years ago in his book “The first three minutes”. Tyson recapitulates the findings of modern astrophysics since 1900 and adds what Weinberg didn’t know at the time of finishing his book.

For this book review, I went back to Weinberg’s expectations as formulated in the *Afterword* of his updated book (second edition 1993) thirty years ago to find out how much of his expectations could be met by the increasingly sophisticated measurement and observation methods. Their improved capabilities have brought forth a discrepancy between two key methods for determining how rapidly the universe is expanding. The currently unknown resolution of this “crisis in cosmology” or “cosmic tension” may lead to a new understanding of the physics laws that govern the cosmos.

To anticipate one result, both books start with the big bang scenario 13.8 billion years ago, without clarifying what caused it or what was before.
This current knowledge also is assembled on the global internet and well expressed in a poem that was created as an experiment by artificial intelligence (AI) on demand using the chatGTP program on January 23, 2023.

Before the Big Bang, there was nothing
No time, no space, no light, no matter
All that existed was a singularity
Infinitely dense, infinitely hot, infinitely small

But then came the Big Bang, the birth of all
The explosion of energy and matter
The creation of space and time
The start of the universe, forever expanding and changing
But what caused the Big Bang, is still a mystery
A question that scientists are still trying to unravel

In Neil de Grasse Tysons’s book it reads like this:
But what happened before all this cosmic fury? What happened before the beginning? Astrophysicists have no idea. Rather, our most creative ideas have little or no grounding in experimental science. Yet the religious faithful tend to assert, often with a tinge of smugness, that something must have started it all: a force greater than all others, a source from which everything issues. A prime mover. In the mind of such a person that something is, of course, God, whose nature varies from believer to believer but who always bears the responsibility for starting the ball rolling.

***Weinberg's expectations in his Afterword in "The First Three Minutes" (1993)***

It is still believed that the universe is expanding, in the sense that the galaxies are rushing apart from each other. It is still believed that the cosmic radiation background discovered in 1965 is red-shifted thermal 'black-body' radiation, left over from a time when the universe was at a temperature of about 3000°K, about 700,000 years after the beginning. It is also still believed that the mixture of light elements from which the stars first formed - 75 percent hydrogen, 25 percent helium, and a trace of deuterium, lithium, etc. - was formed in nuclear reactions when the universe in at least its present expanding phase was about three minutes old.

Although the following issues mentioned in Weinberg's afterword are heavily interconnected, I have decided to divide the subject areas into two categories to make the comparison with Tyson's findings easier.

*1 Hubble Constant and Expansion*

Observations by a Berkeley group using a U2 aircraft have discovered a small anisotropy of precisely the sort that would be expected if our solar system is moving at high-speed relative to the radiation background - that is, a somewhat higher temperature in the direction towards which we are moving, and a lower temperature in the direction from which we have come. When allowance is made for the fact that the solar system is carried along by the rotation of our galaxy, one can conclude that our whole galaxy is traveling relative to the radiation background at about 400 km/sec, more or less in the direction of the rich cluster of galaxies in Virgo. This is a high speed, rather higher than the 100 km/sec or so that used to be quoted as a typical galactic velocity.

One consequence of this view of our galaxy's motion is to change estimates of the Hubble constant. One can conclude then that the Hubble constant is somewhat larger than has previously been estimated - say 30 km/sec instead of 15 km/sec per million light years.[1]

*2. Dark Matter and Dark Energy*

A paradox is evidently upon us. If the total mass density of the universe is really one third to one-alf the critical density, and the density of the baryons is only a few per cent of this, then in what form is the mass of the universe?

Another implication of large galactic peculiar velocities is that there must be a good deal more mass in the Virgo cluster than had generally been supposed. This mass is needed to produce gravitational fields strong enough to accelerate our galaxy to high speed during the time since it was formed. Evidence for large galactic masses comes also from studies of individual galaxies.

Increasing attention has been given lately to the possibility that the missing mass is in the form of massive neutrinos. The neutrino has generally been thought to be a particle of zero mass, like the photon, and for many years there was no sign of any neutrino mass; indeed, there was firm evidence that the neutrino mass is less than about one-ten-thousandth that of the electron.[1]

*3. Inflation, Phase Transition*

Finally, the latent heat released in a delayed first-order phase transition could explain one of the most obvious and yet surprising facts about the universe - that there is so much stuff in it. We know for instance that the number of photons in the universe is at least io87 (a one followed by 87 zeros) and this could be explained by the latent heat released after a super-cooling era in which the universe expands by a factor of io29. Unfortunately, it is difficult to see why the universe should remain this long in the wrong phase, or how if it does it can ever get out of it.

This work [by Alan Guth, Stanford Linear Accellerator] on the very early universe represents real progress, but it is progress of a conceptual sort, only distantly related to observations of the present universe. We are today not much closer than we were in 1976 in understanding the origin of the structures that fill our universe: galaxies and clusters of galaxies. As we look out at the night sky, the great arc of the Milky Way and the faint luminous patch of the Andromeda Nebula continue to mock our ignorance. [1]

***Discussions and Updates in Tyson's "Origins" book***

*To 1: Hubble Constant and Expansion*

Taking the broad view, how should we judge the significance of the current *cosmic tension* [Hubble constant discussions] in cosmology? Like astrophysicists themselves, astute readers may reasonably search for their own biases in predicting a possible resolution. Do you favor a conservative approach, remain calm, and expect that all values will converge to 70 before long? Or do you favor a revolution: a provable confrontation between the values of 67 and 73 that will open the door to new physics? We can be sure that the cosmos itself has no crisis.

The problems arise on Earth, where human understanding inevitably falls well short of perfection. Cosmologists and physicists who see the tension as crying out for a solution have attempted, as their job descriptions require, to resolve it by determining what we have missed in our understanding of the universe. Perhaps to their creators' credit, the list of proposed solutions would overtax most readers. Almost all such suggestions either change the currently accepted model of the universe's expansion history or introduce "new physics," which could include changing relativity theory or the laws of gravitation. The most popular new-physics suggestions involve hypothetical, unknown particles (entirely different from the hypothetical, unknown particles that form the dark matter) or hypothetical, subtle changes in the amount of dark energy during the early expansion of the universe, either before the time of decoupling or soon thereafter. Unfortunately for some of these theories, though fortunately for the progress of science, the precision of our current observations of the cosmic background radiation (CBR) places strong limits on these hypotheses, and in the most straightforward cases, eliminates them with a high degree of probability. From a certain perspective, this increases the excitement that the cosmic tension brings to cosmology: we may find not only that new physics lurks within the seemingly modest disagreement between 67 and 73, but also that the addition of "simple" new physics may prove inadequate. In that case, a wider revision of our understanding would have to occur for the cosmic tension to resolve itself, allowing astrophysicists to concentrate on the new conundrums that will doubtless arise from future observations

*To 2: Dark Matter and Dark Energy*

Dark matter is a substance of unknown nature that produces gravity but does not interact with light in any known way. And dark energy induces an acceleration of the cosmic expansion, forcing the universe to expand more rapidly than it otherwise would. The net effect of our cosmic phrenology exam now implies that cosmologists understand how the early universe behaved, but that most of the universe, then and now, consists of stuff they're clueless about. Profound areas of ignorance notwithstanding, today, as never before, cosmology has an anchor. The cosmic background radiation (CBR) carries the imprint of a portal through which we all once passed along with everything else in the universe.

Observational deduction of how much mass exists in galaxy clusters now gives ΩM (share of Dark Matter) a value of about 0.29, while the observations of the CBR and distant supernovae yield a value close to 0.31. Within the limits of experimental accuracy, these two values coincide. If the universe in which we live does have a non-zero cosmological constant, and if that constant is responsible (along with the matter) for producing the flat universe that the inflationary model predicts, then the cosmological constant must have a value that makes ΩΛ (share of Dark Energy) close to 0.7, more than twice the value of ΩM. In other words, ΩΛ must now do most of the work in making ΩM + ΩΛ equal to 1. This means that we have already passed through the cosmic era when matter and the cosmological constant contributed the same amount (with each of them equal to 0.5) toward maintaining the flatness of space. In less than a decade of astronomical investigation, the doublebarreled blast from the Type Ia supernovae and the cosmic background radiation changed the status of Dark Energy from a far-out idea that Einstein once toyed with to a cosmic fact of life. Unless a mass of observations eventually prove to be misinterpreted, inaccurate, or just plain wrong, we must accept the result that the universe will never contract or recycle itself. Instead, the future seems bleak: a hundred billion years from now, when most stars will have burnt themselves out, all but the closest galaxies will have vanished across our horizon of visibility. By then, the Milky Way will have coalesced with its nearest neighbors, creating one giant galaxy in the literal middle of nowhere. Our night sky will contain orbiting stars, dead and alive, and nothing else, leaving future astrophysicists a cruel universe. With no galaxies to track the cosmic expansion, they will erroneously conclude, as did Einstein, that we live in a static universe. The cosmological constant and its dark energy will have evolved the universe to a point where they cannot be measured or even dreamt of. Enjoy cosmology while you can.

***Note by the Editor***

ESA is following up the search for dark matter and dark energy with a specialized space telescope called “Euclid” to measure the acceleration of the universe. It will be launched on a Falcon 9 –if all goes well – by the end of 2023. [2]
The May Planck-institute astrophysicist and ESA science director Guenther Hasinger pursues another approach since 2020, namely that cold Dark Matter as the sum of different mass Primordial Black Holes (PBH) can explain a number of unsolved astrophysical mysteries. He assumes a broad PBH mass distribution provides the bulk of the Dark Matter, consistent with all constraints, and estimates the baryon accretion onto PBH contributing to cosmic background radiations, mainly the correlation signal between the cosmic X-ray and the cosmic infrared background fluctuations in deep Chandra and Spitzer surveys. His hypothesis looks to be supported by the latest James Webb Space Telescope (JWST) observations of Quasars. [3]

***More “Meditations” by Tyson and Goldsmith***

The *Multiverse* argument gains more traction if we assume, as do many cosmologists, that everything we call the universe belongs to a much larger “multiverse,” which quite possibly contains an infinite number of universes, none of which interact with any other: in the multiverse concept, the entire state of affairs embeds in higher dimensions, so space in our universe remains completely inaccessible to any other universe, and vice versa. This lack of even theoretically possible interactions puts the multiverse theory into the category of apparently non-testable, and therefore non-verifiable, hypotheses—at least until wiser minds find ways to test the multiverse model.

Additional chapters are dedicated to the “Origins” of galaxies and their structures, the origin of stars and planets, and finally, the origin of life.
A detailed discussion would go far beyond the purpose of this book review – just let me ascertain that the level of detail is overwhelming and illustrates the tenacious life-long struggle of the most qualified scientists to embark ever refined satellites and probes to grasp and solve the still numerous mysteries of the existence of our universe and our life in it.

Neil de Grasse Tyson and his co-author Donald Goldsmith present the important milestones on our way to the answers of the old questions, what was before, how did it begin and where are we heading, by explaining the latest theories and findings up to the Hubble Space Telescope and the James Webb Space Telescope (JWST) images, which allowed unprecedented views of “Pillars of Creation” and the JWST “Deep Field image”.

The book is written in a non-too-scientific language, contains an extensive glossary, additional reading references, and a grandiose illustrations insert section featuring all the latest, breathtaking Hubble and JWST images with appropriate interpretations and explanations - the book is a gem!

References


[1] Weinberg, The first three minutes, 1993 update
[2] Eucild, https://en.wikipedia.org/wiki/Euclid_(spacecraft)
[3] Hasinger, https://arxiv.org/abs/2003.05150



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