Understanding Our Only Universe

Valerio Marra — PhD, Assistant Professor
Federal University of Espirito Santo
(Vitória-ES, Brazil)

E-mail: marra@cosmo-ufes.org

In an imaginary dialogue between a professor and a layman about the future of cosmology, the said professor relates the paradoxical story of scientist Zee Prime, a bold thinker of a future civilization, stuck in a lonely galaxy, forever unaware of the larger universe. Zee Prime comes to acknowledge his position and shows how important it is to question standard models and status quo, as only the most imaginative ideas give us the chance to understand what he calls "our only universe" — the special place and time in which we live.

Keywords: cosmology, standard model, dark energy, universe expansion, observable universe

> *Here's to the crazy ones, the misfits, the rebels. The trouble makers, the round pegs in the square holes. The ones who see things differently…*
>
> *Johnny Appleseed*

The influential and fantastically rich Mr Y was eager to meet the Professor and he eagerly knocked on the door of his study. His latest passion was cosmology, and he was keen to conquer the mysteries of the heavens, as he had conquered the world markets. He was invited to sit in a *chaise longue* and straightaway popped the question: "Is it really true, dear Professor that our technology will allow us to observe all the galaxies of the universe? How emotional!"

"Of course", the Professor deftly answered. "In the very near future, we will compile catalogs of billions of galaxies, reaching the edge of the observable universe, and the very first galaxies ever formed".

Mr Y: "Wow! What immense scientific pandect! I will put my chock-full assets in the project… to understand the inner workings of the cosmos, its dynamics, how it all started, how… very emotional!!!"

Professor: I appreciate your enthusiasm, but for the sake of correctness I feel it my duty to add that our universe will not let us uncover its mysteries, easily.

Mr Y: Oh! Still, I trust I will be able to understand what dark energy is, the mysterious something that is counterbalancing the gravity of matter and causing the universe to accelerate ever faster, will not I? We — I mean "we" as humanity — are studying modified gravity, bigravity, exotic sources and interactions… [Amendola et al., 2016]

Professor: I see, Mr Y. You seem quite *à la page*! Let me take up the acceleration of the universe to show you what I mean by "not easily"… and this I can do by telling you the story

of Zee Prime, not a present-day scientist, rather a thinker belonging to a future, immensely advanced, civilization, in a galaxy far, far away.

Mr Y: You are titillating my curiosity, Professor, to hear of a man we will never meet. Please, go on.

Professor: Well, dear *confrère*, Zee Prime would not accept the idea of a static universe… "*Everything we observe evolves*" he ponders "*stars and nebulas… why should the universe be static?!*" And he sums up what results his science has reached with the following words:

> *According to the standard model of the universe, our star is but one of the billion stars which are distributed in a disk-shaped structure surrounded by a spherical halo of weekly interacting particles. It is located on the quiet outskirts of the cosmos, beyond which nothing exists. Total darkness. Or, more precisely, the asymptotic flatness of spacetime.*

The Professor paused and, almost assuming the character of Zee Prime, continued with his exposé:

> *Hydrogen is less and less abundant and so are the few new stars. The monstrous black hole at the center of the universe grows ever bigger. And so does the entropy. However, despite our detailed understanding of the cosmos, many fundamental questions are still unanswered: How did the universe come to exist? Why the initial hydrogen and helium? Why does the universe have a center?*

Mr Y: What fearful questions, Professor, you ask… me! I thought the future was much more relaxed, on the *chaise longue* of a masterful observation…

Professor: Questions, yes… but Zee Prime is bothered by something even more fundamental. He is constantly trying to find a way to see evolution in the universe, in its space-time. And finally, he succeeds in formulating the right question, quite comprehensible by everybody, Mr Y, nonetheless suitable for mathematical interpretation: "Which evolving space-time could look like the static space-time that we observe?" Zee Prime delves into the study of gravitation, especially of its lesser-known literature. He finds old mathematical papers dealing with the homogeneous distribution of matter. Astronomers had never taken these works seriously; according to the standard model, matter in the universe is not homogeneously distributed. These works talked about dynamical universes!

He is caught by such fury of thought, such fury, Mr Y! I can imagine his very words:

> *I think that perfect homogeneity is of course an idealization. If there are clumps, surely gravitational collapse makes them grow. They must have a center, just like our spheroidal universe!*
>
> *Oh! A new dimension opens up in front of me. Our universe is but a tiny speck of a much larger universe. A universe that contains who knows how many universes such as ours!*
>
> *A real paradigm shift, a new way to look at the cosmos… it follows, it follows that…*

Mr Y, are you still with me? I can hear Zee Prime talk to himself:

The clumps must have distanced themselves, the universe is expanding! Its expansion must have gone on so fast as to beat their gravitational attraction. Vacuum energy could easily do the job. It follows that we do not see other clumps other than our own universe. Our clump would be left alone aging towards its thermal death. Finally, if the universe is expanding, in the remote past it must have been denser.

Zee Prime stops and ponders. And then he proceeds again with such fury of thought, such fury, Mr Y!

Mr Y: Goodness me! My *chaise longue* is becoming an interstellar capsule. Where are you taking me, Professor?

Professor: I am taking you into the very far past… to a primordial time when our whole observable universe could be put inside your pocket.

Yes, the universe must have been hot, a plasma of elementary particles, and before that a plasma so hot that one would actually need to quantize the spacetime. As the universe expands and the plasma cools down, atoms would form, hydrogen, helium and their isotopes.

Zee Prime freezes for an instant, Mr Y, aware of how momentous his perspective is:

I can predict the abundance of light elements! My theory is not pure speculation! Moreover, at a sufficiently low temperature the plasma would become transparent, therefore an image of the hot plasma just before this moment could reach us. Still, we do not detect any uniform electromagnetic radiation… but, again, we do not observe any other clumps and the reason is the enormous expansion of the universe! This radiation has been diluted away!

Mr Y: I am feeling so flustered about the future, Professor! I suddenly recall these words:

Tomorrow, and tomorrow, and tomorrow
Creeps in this petty pace from day to day
To the last syllable of recorded time
And all our yesterdays have lighted fools
The way too dusty death.
(*Macbeth*, V, 5, 19-23)

(Knocking on the door)

Somebody knocks at the door, Professor. “Knock, knock, and knock. Who is there, i’ th’ name of Beelzebub?” (*Macbeth*, II, 3, 3)

Professor: Let them knock! This knocking is not for Zee Prime. It is a new theory, Mr Y, with so much to do. Zee Prime crunches the numbers. He finds that his theory can work, or better, it is not falsified by observations. Indeed, star formation has fused at an uncertain rate most of the primordial hydrogen into helium. Predictions could not be sharp without observing the forever gone larger universe [Krauss & Scherrer, 2007].

Mr Y: But let us call a spade a spade, you started by saying that for Zee Prime the universe was static!

Professor: Exactly! Zee Prime concludes that the universe expansion has been so accelerated as to separate our universe from other universes, to darken everything from view but the very galaxy in which he lives [Linder, 2008], leaving us prisoners of what appears to be a static island universe… [Rothman & Ellis, 1987]

Mr Y: What ironic *débâcle*, the speed of the universe expansion being so much faster than our progress in observation!

Professor: But mind you… Zee Prime is not over yet!

Who would believe such a theory? The universe being accelerated by vacuum energy… How can we conclusively test it?

A luckier observer might have lived in the past when more of the actual universe was observable… well, if we have nothing out there to see, we could put something there ourselves! We could send out probes [Kwan *et al.*, 2010]*... or even better, there may be natural beacons out there* [Loeb, 2011]*, we never really tried very hard to look into the nothingness outside our only universe, why should have we?!*

Mr Y remained silent, busy trying to rearrange his logical circuits. Eventually he spoke: You prefigure a most advanced civilization with a cosmological model similar to the one we had in the early 20th century, before Albert? Am I right?

Professor: Exactly.

Mr Y: That is not just ironical, that is cruel towards our ambition to comprehend the grand universe.

Professor: It is up to the universe to give the rules of the game, not up to us, nor any advanced society. Is this diminishing your interest in cosmology?

Mr Y: On the contrary! Making advances into this "quest" appears to me, I would say, greatly heroic, highly interesting, and worthy of my full dedication. Zee Prime manages to get a glimpse of what was hidden from him and his peers, does he not? And they may be able to prove his theory…

Professor: Yes, indeed, but only because Zee Prime stopped thinking along the lines of the standard model. "It is the theory which decides what we can observe" [Heisenberg, 1971: 63] and our theories do not necessarily reflect the cosmic age in which they are invented [Rothman & Ellis, 1987].

(a robust knocking on the door)

Mr Y: Please, let the porter in!

Porter: You are late! Your PhD students, Macduff and Lenox, are waiting for you, Professor Zee Prime! *(he flies out)*

Mr Y: Zee Prime! You are Zee Prime? Where am I, for goodness sake!

Acknowledgments

The author is deeply grateful to Giulio Marra for many important suggestions throughout the development of the manuscript. It is a pleasure to thank Daniela Baroni and Fabiana Vasconcelos Campos for useful discussions. The author is supported by the Brazilian research agency CNPq.

🕮 References

Amendola, Luca et al. *Cosmology and Fundamental Physics with the Euclid Satellite*, arXiv:1606.00180, 2016.

Heisenberg, Werner. *Physics and Beyond: Encounters and Conversations*. Translated from the German by Arnold J. Pomerans. Harper & Row, 1971.

Krauss, Lawrence M. and Robert J Scherrer. The Return of a Static Universe and the End of Cosmology. *Gen. Rel. Grav*. 39, 2007:1545–1550.

Kwan, Juliana, Geraint F. Lewis, and James, J. Berian. The Adventures of the Rocketeer: Accelerated Motion Under the Influence of Expanding Space. *Publ. Astron. Soc. Austral.* 27:15, 2010.

Linder, Eric V. Mapping the Cosmological Expansion. *Rept. Prog. Phys*. 71:056901, 2008.

Loeb, Abraham. *Cosmology with Hypervelocity Stars*. JCAP 1104:023, 2011.

Rothman, T. and G. F. R. Ellis. The epoch of observational cosmology. *The Observatory* 107, 1987: 24–29.