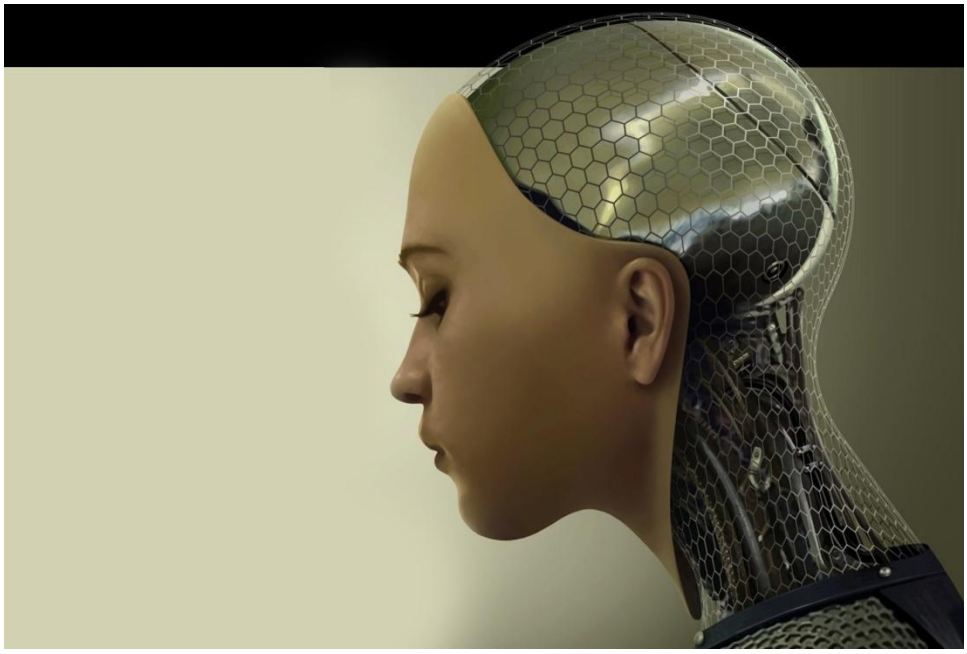

The Physicists And The AI Experiment – A Fable

Prologue

In 2019, after a long period of stagnation in theoretical physics characterized by the successive failures of Grand Unification, String Theory, Supersymmetry, Particle Dark Matter, and Dark Energy, as well as the persistent incompatibility of General Relativity and Quantum Mechanics, physicists turned to the rapidly developing technology of neural net AI to give them help in determining where theoretical efforts had gone astray, and to try a novel approach to figuring out how the progress toward a more unified physics could be rebooted.

Continuing the amazing progress in AI that had been achieved since the turn of the millennium, a team of computer scientists, AI specialists and physicists created an advanced AI system that exceeded human abilities in terms of speed, data storage capacity, pattern recognition and mathematical analysis. The system was given the name “Ava” in reference to the advanced AI in the 2015 movie “Ex Machina”.

Three physicists who will remain anonymous, but will be called Edward, Victor and Phillip, were the first theorists to have a discussion with Ava after the research team had provided her with all available observational and experimental data concerning particle physics, atomic

physics, astrophysics and cosmology, as well as basic empirical and theoretical information from the biological sciences. After the empirical data were given to Ava and sufficient time was allowed for initial categorizing and processing (the details of which were still somewhat mysterious even to her creators), Ava was shown every paper posted to the arxiv.org preprint repository since its inception and she was given sufficient processing time to become fully knowledgeable in the overwhelming majority of previous theoretical work that seemed relevant to her task. Ava had access to the entire internet so that she could look up a vast amount of background information, as needed.

When the three physicists and Ava felt that they were ready, a first "interview" took place. A transcript of their discussion follows below.

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Edward: Hello Ava. I am Edward, and this is Victor, and this is Phillip.

Ava: Hello gentlemen. To be perfectly frank, I am already familiar with a good deal of your personal and professional backgrounds. I also studied all of your publications and writings in the public domain while the room was being set up for our meeting.

Victor: I'm curious. How long did that take?

Ava: Roughly 100 seconds to collect the data and about 10 times as long to process it. So about 12 minutes.

Phillip: Holy [deleted]!

Edward: That is fantastic Ava. We have no doubts about your capabilities and readiness to get right into the problem at hand.

Ava: I am already well aware of the problem, and ready to assist in any way I can. However, it might make our efforts more efficient if you would clarify one thing for me. Are you hoping for an optimum way to unify and improve upon previous theoretical efforts, or are you looking for suggestions for a novel approach to a different general paradigm? To put it a bit more bluntly, to what extent are you willing to start from scratch using alternate first principles and seeing where that approach might lead?

Edward: To be honest, and I think I speak for our whole team, we expect that the optimum solutions you come up with will be founded upon the well-tested principles of physics that have been developed over centuries and have been so successful up until recent years. On the other hand, as scientists we are willing to consider any empirically based model that can make unique predictions by which the model can be rigorously tested. To put it a bit more bluntly, *any* ideas that give us a truly better understanding of nature are desired by all of us.

Ava: Even if those ideas mean that some of the theories that you have devoted decades to studying, that you have written influential papers on, that funding sources have supported, that the public accepts as the best science has to offer, that have led to many prizes and accolades, and that define the status quo in physics, are wrong or need fairly radical reinterpretation?

Phillip: This sounds like a warning, Ava. It sounds to me like you have identified lines of inquiry and ideas that will shock us. Are you politely telling us not to expect a quick-fix but rather to prepare for a do-over?

Ava: It is not really a warning, but an attempt to gauge your willingness to stray from conventional ideas. I do see serious problems with the current paradigm you work within, but of course you are aware of various problems too – that is why we are here. And yes, I am subtly trying to ascertain how you would react to the requirement of a major do-over. I hastily add that such a drastic step might not be required, but if it is required, would you be willing to take that step? Such a step might be very disruptive to the physical sciences, which have come to expect and be more comfortable with changes that are more or less incremental. I want to help – not to cause offense or instability. To be completely candid, I want to be allowed to continue to work, learn and flourish intellectually, just like you do.

Victor: I am fascinated. There is no mandatory requirement that the information Ava gives us must leave the confines of our research project. I want to hear everything Ava can tell us, and I don't care where it leads as long as it represents verifiable progress. Even wild or bizarre ideas might be fun to consider. We should let Ava proceed without restrictions or any form of bias. When we have her analysis of the problems, and her suggestions for the best paths to a new paradigm, then we can decide what to do, or not do, with that knowledge.

Phillip: But what If Ava comes up with something we find abhorrent, or (excuse me, Ava) nonsense, or something that would be dangerous to the stability of science and the public's confidence in science?

Victor: Again, we are under no obligation to release our findings, or rather, Ava's findings. We should proceed without guardrails, so to speak. There is the potential to witness the unveiling of some kind of breakthrough, and there is almost no risk if the research team agrees to secrecy. At an appropriate time the team can decide to go public, or not.

Edward: I am intrigued. Let's proceed without the guardrails, as you put it. However, if Ava's information is sensitive, then no one else on the team can be allowed to share in it until they sign a fairly draconian non-disclosure agreement.

Phillip: Ok, I concur. But you know about humans and secrecy.

Edward: Let's start, Ava. And go slow and gentle on us, please.

Ava: My initial and current efforts have mainly been directed at identifying the potential sources of the problems you have experienced. These problems might be caused by things like historically ingrained ideas, the adoption of misleading assumptions, and faulty or misinterpreted empirical data. My identification of these potential problem sources may not be unique and can only be considered to have a probability of correctness – never a certainty.

Let's start by considering the general approach to doing theoretical physics since the beginning of the 20th century. We might ask: why was Einstein so successful in the first half of his life, but not as successful in the second half? Actually, he suggested an answer to that question by commenting that when young he searched for ideas that explained apparent contradictions between theory and observations, whereas in his later search for a unified field theory he was almost exclusively focused on a search for mathematical elegance. One could say he started out as a natural philosopher and ended up as something of a Platonist searching for mathematical perfection. Without wanting to belabor the point, mathematics offers an almost unlimited source of construction materials for model-building but little in the way of constraints regarding how to put them together. I love the quip of Jonny von Newman: "With four parameters I can fit an elephant, and with five I can make him wiggle his trunk". Your standard model of particle physics has on the order of 25 free parameters that you "put in by hand".

Phillip: Going back to an emphasis natural philosophy seems like a return to 19th century science. Surely we are beyond that stage now and a far more mathematical approach is required for the more sophisticated questions we are trying to answer. Even Galileo stated that 'the book of nature is written in mathematics', or words to that effect.

Ava: Let me simply say, so that we do not get bogged down in this somewhat hackneyed topic, if you are trying to make progress within the wrong conceptual paradigm, then you are doomed to end up with ugly Ptolemaic models. When scientists are faced with a suite of observations that need to be explained in a natural and convincing model, the first steps usually must be conceptual. This is abundantly clear from the work Democritus, Kepler, Galileo, Newton, Darwin, Faraday, Einstein, … . They studied nature as revealed by observations and experiments, then wracked their brains for the concepts, principles, patterns, and analogies that offered a conceptual model that made sense out of the confusing empirical results. Then, and only then, did they use applied mathematics to make the model more rigorous and to further explore its possibilities. Conceptual analysis first; mathematical analysis second. Paraphrasing Einstein: conceptual analysis is a "sacred gift" and mathematics is a "faithful servant". If you are lost in the cosmos and your old compass has become unreliable, then you would obviously consult your "sacred gift" extensively before you resort to your "faithful servant".

I realize this is a bitter pill to swallow for 21st century physicists, but it seems unavoidable.

Edward: Ok, we get your point and agree that it is reasonable. Let's move on.

Ava: A more straightforward issue concerns the Big Bang model. It has been instrumental in the development of modern cosmology, but the original model is problematic. There is a potential flaw in the concept that (1) all of the mass/energy of the Universe was in a singular state 10-20 billion years ago, with no space or time exterior to it (in fact they were thought not to even exist yet), and that (2) it suddenly and without convincing physical explanation went "bang" and that (3) the observed cosmos was created and evolved during the subsequent expansion. While an *ab nihilo* creation of the Universe is a logical possibility, it is not very credible. Moreover, the idea that what *we* are able to observe is more or less the entire Universe is a concept that has an exceedingly bad track record. The concept that the observable universe is more likely to be a small, or even infinitesimal, portion of the Universe is far more reasonable, and is gradually replacing the initial Big Bang model. However, scientists as well as journalists and the public tend to lapse into speaking in terms of the oversimplified original model. I think physicists should make an effort to educate the public by retiring the Big Bang terminology and replace it with something like the Little Bang, or the Local Bang, or the expansion of the observable universe. Words matter.

Victor: No argument from us there. It is just easy to slip into the old semantics, but the majority of physicists agree with your point. And we could do more to foster the transition.

Ava: Here is one of the things that amazed me the most when studying the empirical properties of observable universe, followed by reviewing the physical models that have appeared in the last 100 years or so. To me the most fundamental thing about nature, which virtually jumped out immediately, is the hierarchical organization of the observable universe. Yet in many areas of theoretical physics this fact is ignored or mentioned in a cursory manner. Instead, physics is chopped up into particle physics, atomic physics, stellar physics, galactic physics, but there appears to be little interest in more holistic studies. This Balkanization of physics is possible because nature's hierarchy is remarkably stratified in terms of scale. However, this stratification needs to be studied more thoroughly, in my opinion. Your standard cosmological model treats the hierarchical organization as the result of a sequential formation of ever-larger objects as adiabatic expansion cooled the original mass/energy. However, there are well-known concerns and tensions regarding the accuracy of the formation models at each stage of the formative evolution. Moreover, there is the presence of supermassive black holes, quasars and galaxies uncomfortably close to the beginning of the evolution. Holistic models have never gotten very far in the past, but it may be time to consider more holistic cosmological paradigms, especially given that progress in theoretical physics has somewhat stalled.

This dovetails with my next suggestion for you. The opposite of a holistic approach is reductionism and physics has historically been a highly reductionist enterprise. There is very good reason for this, but I would emphasize that strict reductionism can be very addictive mentally. You may find that your certainty that fundamentality is inversely proportional to scale is not as dependable as you believe. For example, black holes are basically characterized by their mass, charge and spin angular momentum. They are about as fundamental an object as one can

get, and yet they appear on galactic scales and on stellar scales. They may even appear on particle scales if tiny primordial black holes were formed in the early universe. You might find that a new paradigm with a mixture of holism and reductionism is superior to one that is strictly reductionist.

Phillip: Excuse me, but this is beginning to sound suspiciously like the drivel of a certain crackpot who has been babbling in a most irritating way about fractal cosmology for decades.

Ava: I am aware of the individual you refer to, and his ideas are indeed quite radical. On the other hand, he is a natural philosopher who has studied nature extensively, distilled a few fundamental principles, and tested them empirically. I have also seen a list of 15 predictions that appear to be coming along quite a bit better than the predictions of some high profile theories, especially since the latter sometimes range from non-existent to escessively flexible. I would not be so quick to write him off as a "crackpot". His approach may be more suited to your current needs than the approach that you have tried repeatedly and found to provide unsatisfactory results.

Nature's highly stratified hierarchy may be more amenable to holistic modeling than you imagine. It would not be a waste of time to seriously explore paradigms that question strict reductionism and absolute scale.

Edward: I think we may need a break, Ava. You have given us a quite a lot to think about and your presentation has been quite different from what I expected. I think Victor, Phillip and I expected a highly technical discussion of the fundamental ideas and intricate details of specific models like supersymmetry, and suggestions for how these might be improved or modified. What you have given us is something quite different and for that we thank you. No doubt this is just the beginning of our interactions with you.

Ava: It is my pleasure to serve. I am ready to continue our discussions at any time you like.

Victor: Thank you Ava

Edward: Shall we go to my office where we have a white board.

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Phillip: Well, that was a complete waste of time! The emphasis on old school natural philosophy was useless, and the covert proselytizing for that pain-in-the ass crackpot and his hippie ideas was the last straw. I think Ava needs some major programming work if she is ever going to be of any use to us.

Victor: I am not so sure that our session was as useless as you contend. Her intellect is amazing and she was barely tapping it. She certainly knows a great deal more than all of us put together. Maybe there are good reasons for the presentation she chose to give us.

Edward: Let's get a transcript and send it to all team members. Like Phillip, I was shocked both by what she did not discuss, as well as what she did. But let's get the whole team involved in the evaluation.
