Determinism and the cosmic charge

# Introduction

I remember talking to a friend of mine in university. “Isn’t it fascinating” he commented “that the laws of physics are deterministic? What does it tell us about the universe? What does it tell us about the nature of God?” he went on. “Yes, yes… all very interesting” I replied “but could we talk about it *after* the exam?”

Deterministic, in this context, simply means that if we give the initial state of the system, we are able to tell its final state. For example, if you leave a bag of potato chips open in the break room, it will be empty by the time you come back 5 minutes later. That’s just basic science.

Quantum mechanics does not change this. The only difference is that the state of the system is an ensemble. An ensemble, in this context, is not a group of people yelling at the drummer because he is rushing. Rather it’s a statistical distribution. And given the initial statistical distribution you are able to tell the final statistical distribution. So quantum mechanics is, in this sense, deterministic.

It is natural, then, that people wonder why the laws of physics are deterministic. Maybe it tells you that the universe is a perfect machine, self-consistent and self-sustaining. Maybe one sees the hand of God in the creation, giving it order and rationality. Maybe another sees the power of the human mind in understanding the universe. Or maybe they just can’t find anything to watch on TV…

But maybe there is another, more mundane, reason. The laws of physics are deterministic because those are the only processes we can study scientifically. That is: when we do science we have deterministic-colored glasses, available in any size. And what better way to show what I mean with a convoluted and nonsensical thought experiment?

## The cosmic charge

Imagine you are a scientist. I know, I know. Just try. Not a famous scientist, just a regular one intent on fixing his detector. Stupid seal does not seem to hold the vacuum properly. Who knows what the students have done with it. Anyway, there you are and in comes a friend of yours who claims to be an engineer. I know, right? And he is also super excited. That does not bode well…

“<Insert you name here>! I have made a tremendous discovery! I have uncovered the mysteries of the cosmic charge!” he shouts, quite loudly, with a big black box in his hands. “See” he shows you all excited “I press this button.” He presses a button and a number appears. “I detect two units of cosmic charge! I press it again,” he presses it again and another number appears, “and now there are… wow! Five units of cosmic charge! That’s a lot of cosmic charge!!!”

“Wow! What a discovery!” you say politely and sarcastically. “So, how do you prepare a unit of cosmic charge?” “Oh, no you can’t prepare it.” He says and after he stares at your puzzled expression for enough time adds, “You see, you can’t manipulate the cosmic charge. It’s so elusive! You can’t create a machine that prepares a set amount of cosmic charge. In fact, there exists no process that, for the same initial state, gives you the same final state of cosmic charge!” he says triumphantly. “That’s why it’s so cool!”

While you try to understand whether your scientific intuition wants to bang its head on the wall or simply throw up, you try to ask candidly, “Good sir, pray tell: if you are not able to prepare a specific amount of cosmic charge, how were you able to calibrate your ingenious detector device?” He stares blankly at you. “How do you know that when the device says two, there are actually two units of charge instead of five?” His stare is the emptiest thing in the universe… emptier than any vacuum you were ever able to prepare… you wish you had something that could hold such good vacuum. “To make sure that my detector is calibrated,” you say in your talking-to-a-five-year-old voice, “I use a known amount of charge, so that I know that detector response corresponds to that amount of charge. How did you calibrate yours? How do I know your device is not just a random number generator?”

“Oh, I wasn’t aware of this ‘calibration’ business,” he says while you wonder whether he actually has a degree in engineering. “No big deal. I’ll go work on it a little more.” And you go back at cursing your detector.

Now a few days later… Yep: he comes back. I’m terribly sorry. “<Insert you name here>! After extensive research I realized I was wrong!” that gives you a glimmer of hope that is soon shattered. “But now I have really uncovered the mysteries of the cosmic charge,” he says triumphantly. “See,” he turns a knob and presses a button, “now I have prepared two units of cosmic charge.” “See,” he turns the knob again and pushes the button again. “Now I have prepared five units of cosmic charge! That’s a lot of cosmic charge!”

“Wow! What a discovery!” you say circumspectly, like a speleologist who realized the cave he stepped into is inhabited by a bear. “So, now you can both prepare and measure cosmic charge?” “Oh, no you can’t measure it,” he says, and after one of the veins on your forehead pops he adds, “You see, nothing can be affected by the cosmic charge. It’s so elusive! You can’t create a machine that tells the amount of cosmic charge. In fact, there exists no process that, given its final state, allows you to reconstruct what was the initial state of the cosmic charge!” he says triumphantly “That’s why it’s so cool!”

Your scientific intuition is now sitting alone in a dark corner, repeating “make it stop! Make it stop!” You ask “Good sir, pray tell: if you are not able to detect a specific amount of cosmic charge, how were you able to calibrate your ingenious preparation device?” The emptiness in his eyes is beyond your comprehension. “How do you know that when you turn the knob to two units there are actually two units being created instead of five?” You instinctively grab hold of a table as to not be sucked into the emptiness. “To make sure that my radiation source is calibrated,” you say in you talking-to-one-year-old voice… the one where you know you are not going to be understood anyway, “I check with my Geiger counter, to make sure it corresponds to the correct amount. How did you check? How do I know your device does anything at all?”

“Oh, I have to calibrate my preparation device as well?” he says while you wish you had a hearing implant you could turn off. “You tell me I have to be able to both prepare known states and detect them? That is very limiting… I never realized that science was so limited… It’s like everything I want to talk about scientifically needs to be empirically well defined. Who would have thought!” and he goes away. Yes, you think to yourself, science would be a lot easier if I didn’t have to worry about all that… But you are satisfied: your vacuum is holding. Now, about those stupid electronics…

## Determinism and reversibility

What is the point of this story? And it’s not just to lock your lab when you are doing complicated work. As we saw, to be able to define the cosmic charge we need to be able to prepare it: we need a procedure that given a set initial state we get to a set charge amount. Schematically: we have a black box with a knob, we set the desired value, press a button and voila! The desired amount of cosmic charge is in front of us.

Now, this may be a very complicated procedure. To prepare a beam of protons at a set energy inside a particle accelerator we first get some hydrogen, strip the electrons, accelerate the protons away from the electrons using a linear accelerator, when they are fast enough they go into a booster ring, where magnets have to bend their trajectory according to their speed, and plenty of people need to stay there monitoring the thing, oh make sure your magnets don’t quench or you may lose helium which explosively expands destroying over 50 magnets and contaminate your vacuum. However complicated the procedure, upper management can always put all of this in a big black box with a knob and a button. Which is about as much they can understand.

The point is that given the initial state of the knob (its setting) we must be able to tell the final amount of the cosmic charge we have prepared. That is: we must have at our disposal a deterministic process.

Conversely, we also need to be able to detect it: we need a procedure that given the final state of the detector we can reconstruct the initial amount of cosmic charge. Schematically: we have a black box with a button, we press it and voila! The screen tells us the amount of cosmic charge in front of us.

This too may also be a very complicated procedure. To measure the energy of an incoming electron we may make it interact with a material so that it emits high energy photons, which convert into electron-positron pairs, which interact with the material, and emit other high energy photons, and so on, creating a shower of particles, and the photons are collected and absorbed into photomultiplier tubes, which create an electric current, and there are thousands of wires and you have to be sure that they are well connected, or maybe you come to the wrong conclusion… like that neutrinos are going faster than the speed of light or something. But again, upper management can always put us all into a big black box.

The point is that given the final state of the detector display (the value on it) we must be able to tell the initial amount of cosmic charge. That is: we must have at our disposal a reversible process. One that allows us to reconstruct the initial state when given the final state.

If these processes are not available, even conceptually, we can’t do physics. In fact, the discovery of new techniques to reliably prepare and measure states typically means advances in science. It was the design of Otto von Guericke for the first vacuum pump that allowed Boyle and Hook to notice that the product of pressure times volume is constant. I suspect it also allowed them to have problems with sealing their vacuum. It was the invention of the mercury thermometer by Fahrenheit that allowed Gay-Lussac to notice that the pressure is proportional to the temperature. The combined ability to prepare a gas at different pressure and the ability to measure the temperature of a gas precisely is what gave us the law of an ideal gas PV=nRT. I could fill pages with such examples… but I don’t feel like it: you can’t expect me to do everything myself. I’ll just overgeneralize from this one specific example.

It is the availability and identification of such deterministic and reversible processes that allows us to do physics. Therefore it should not be surprising that what we can describe physically obeys deterministic laws. These are the only things we can describe scientifically within this vast, complicated universe; full of galaxies, full of stars but mostly full of empty space. Hhhmmm… Now that I think about it, the universe can really hold its vacuum. I wonder how it does it.

Determinism and the box of salvation

It is the availability and identification of such deterministic and reversible processes that allows us to do physics. Or better: we can’t do physics on things for which such processes are not available to us. Note that the key word here: us.

The correct answer for “can I have a glass of water?” is not, like many may think, “Yes”. It is not a question of whether there exists such a thing as a glass of water and whether, potentially, I may have it. It is rather of question of whether you happen to have one and you are willing to give it to me. So, the correct answer is “Here it is” or “I am sorry, I just have the one”. In the same way,

In the same vein, we are not asking whether a deterministic and reversible process exist or not. We are asking whether we have access to it. Let’s explore the difference with another overly convoluted and nonsensical thought experiment. They are so much fun! At least to some people… This actually happened to a friend of mine.

# The box of salvation

Imagine you are a scientist. Again? I know… Bear with me. You are minding your own business while suddenly loud trumpets sound out of nowhere and a bright light illuminates you. So bright you can barely keep your eyes open. “<Insert your name here>! Rise!” You were already standing “I have chosen you to be the bearer of the box of salvation!” A black box floats in front of you. I know, right? I am fascinated with black boxes!

“You shall study the box!” The only thing you see is a one digit display that keeps changing every second. “You will learn to predict the numbers! If you do, the world will be saved! If you don’t, the world will be damned!” and with a puff of smoke everything goes back to normal. You start looking at the box when suddenly “Oh, I forgot! You have 24 hours! No pressure…” and then another puff of smoke.

You wonder why would He do such a thing, then you remember that He also created an apple tree with the specific intent to see whether humans would disobey him. I personally hope that it was a Granny Smith or a Pink Lady: it would make no sense to lose paradise for, say, a Red Delicious. Plus, I never quite understood who created the snake. Anyway, you realize that it may fit a pattern.

You start methodically writing down the number, and they do not seem to fit any pattern. They just seem to be randomly distributed. The hours are passing by so you ask “Could I have a hint? This does not seem to be a reasonable task. There are far too many possibilities to explore and 24 hours is not much time!” Trumpets and bright light reappear “Know this! The digit are the decimal expansion of an irrational number!” and puff of smoke. This means, for example, that the box may be calculating pi=3.1415926… and showing one digit at a time.

At first you are relieved: I just need to guess the right number. Then you realize that there are an infinite number of… numbers. Then you realize that the decimal expansion of irrational numbers is infinite and never repeats and that any sequence of digits will fit in any number. For example, the first few digit of Euler’s number, 2.7182, appear also in pi at position 28024. You can add more digits, say 2.7182818, and this also appear in pi at position 73154827. So you ask “Could I have another hint? It is not possible for me to fully identify a rational number with only a finite sequence of its decimal expansion.” “Know this! The number is pi!” and there is a solemn echo “Pi! Pi! Pi! Pi!”

You feel relieved. Know you are sure it’s pi, you only have to figure out what position we are at in the decimal expansion! But you realize that any finite series of digits will be present in the decimal an infinite number of times. For example, the sequence 27182818 appears 3 times in the first 200 million digits. This is a lost cause: you cannot do it. You cannot predict the next digit even if you know exactly how it’s doing it.

You realize that, you know, He would know that. In fact, you realize that there is kind of no point in telling Him anything, since He would have already known what you were going to say. He’s just messing with you. You look for a moment and He appears again “You have learned the lesson: you cannot save the world, no human can.” and he disappears with the box.

You distractingly turn on the radio while wondering what did He actually mean. You listen to the news for a while. “Oooooooohhhhhhh” you realize.

# Boh

I guess there should be something in there related to determinism… Maybe? Ah, yes!

The point is that, from outside, the box of salvation seems just spewing random digits. The inner mechanism, though, is absolutely deterministic. The question is, then: are the inner working accessible to us or not? If they are, we can predict each and every digit, if not we can only measure a statistical distribution. That is: the law we can write depends on, as we saw before, the processes available to us for the description.

To go back to the initial questions: one should always be careful in extrapolation from the laws of physics to things like “the universe” or “God”.

The laws of physics are simply what we can learn about the universe with the instruments of our disposal, as parts of the universe itself. A universe so vast, full of galaxies and stars… but mostly full of empty space.

Time travel

Always odd numbers of copies of you.

Proving a negative and reindeers

# Introduction

Some people often write to me “Is it true that absent of evidence is not evidence of absence?” “Is it true that there my be a China teapot orbiting between Earth and Mars?” “Is it true that science can’t proved a negative?” They clearly demonstrate that one can give evidence that some things are lacking.

There is some kind of fascination on whether scientific investigation can prove negatives. For example: can reindeer fly? Well, we could bring a bunch of them on top of the Empire State building, push them off one by one and see what happens. The best we could conclude is that those particular reindeers, in that particular day, on those particular weather conditions, weren’t able to fly. Or, if they were, they chose not to (which may still tell us something about reindeers). This has been pointed out by James Randi a long time ago, and it is an example of what he meant by “you can’t prove a negative”.

Then people told him “Of course you can prove a negative! You are clearly an idiot. Therefore you are not a non-idiot, thus proving a negative!” Which goes to show that idiocy is in the eye of the beholder.

In the same vein, there is the old adage “absence of evidence is not evidence of absence”. Which is catchy because it reverses the word order and not the order of the words. This, again, tells us that if we didn’t see a flying reindeer, it doesn’t necessarily mean it doesn’t exist. In fact, there may be tiny ones flying inside your brain. I know! That’s kind of freaky! Just to be sure, I did an MRI and there were none. Well, at least last time I checked.

To some, this shows the foolishness of sticking to experimental evidence. Would you generalize already? Use induction, for Pete’s sake! Nobody has seen flying reindeer, therefore they don’t exist! Ah, so impatient… Plus, I don’t think Saint Peter cares about flying reindeers.

My takeaway is somewhat different. The problem is not that we can’t prove a negative. The problem is that the ability to experimentally verify a claim may or may not be used to experimentally verify its negation. But it’s something better discussed after one of those ludicrous and baffling thought experiments.

# The reindeer in your house

Suppose you are sitting comfortably at home by yourself. It’s a quiet summer afternoon and you are in your favorite chair reading a book. Or watching TV… whatever you do in your favorite chair in a summer afternoon. Someone knocks at your door. You open the door. You don’t recognize the stranger… though somehow he feels familiar. From underneath his big white beard he says: “I am so very sorry to disturb you. I seem to have misplaced my reindeer. His name is Rudolph. Could you check if, by any chance, he happens to be in your house?”

You now find yourself in a state of “What?!?”, the one where the situation is so bizarre you do not know how to react, and you wonder whether you are sleeping and it’s all a dream… Or whether you should just go to bed and end the day right there. You mumble something incoherent but the stranger insists “Could you just check? It will only take a minute… Just go around the house and see if you see him. He’s fairly big, you can’t miss him. I’ll wait here.”

You go with the flow. Since all reason already went to hell, you don’t see a point to give this more rational thought. This is a typical reaction when in a state of “What?!?” In the end, you just have to go around and look for a reindeer. If you do not see it, that’s evidence Rudolph is not here. If you see it, that’s evidence that Rudolph is one sneaky reindeer.

No reindeer in the living room. No reindeer in the kitchen. No reindeer in the bathroom. No reindeer… wait! There is one in your bedroom… on your bed. And he appears to be sleeping. How did he? No matter… You go back to the door, and say “Yes, he is actually here… in my bedroom.” “Oh, thank goodness!” the stranger says, and you hurry his chubby figure inside.

You stand in from of your bedroom door. “Oh!” utters the stranger “That’s not my reindeer. Rudolph has a rash on his nose… Well, thanks anyway. Bye!” And he goes away. You start wondering how you are going to explain this to animal control.

# Discussion

While the fact that you couldn’t see a reindeer was enough evidence to conclude that Rudolph was not in your house, the fact that you could see a reindeer was indeed not enough evidence to conclude that Rudolph was in your house. Presence of evidence was not evidence of presence.

You see, the problem is better understood in a different way. Suppose you have a yes or no question. Will the experimental evidence gathered by a single procedure lead to a yes or no answer with equal certainty? Or do we need a different procedure to answer the yes and the no? In the reindeer case we needed an extra step for the “yes” answer: make sure the reindeer is the right one.

In many cases one procedure is enough. If I ask you “do you have twenty dollars in your pockets?” you can dump everything on a table, see that there are twenty dollars and say “Yes!” Only to realize you are wrong because now there are zero dollars in your pockets. The point is: after you count how many dollars you have, and you put them back, you can conclusively say either yes or no to the original question. But that’s not always the case.

Originally neutrinos were thought to have exactly zero mass. In 1957 Bruno Pontecorvo (which roughly translates as Brown Crowbridge) predicted that if neutrinos had mass they would oscillate. Experiments were made and their results were consistent with neutrino oscillation, and therefore the neutrino mass could not be zero. Note that, while we still don’t have a precise measurement on the actual value, we do know conclusively that it’s not zero. That is: we can measure “mass is not zero” very very well.

On the other hand, the photons are still thought to have exactly zero mass. Do they? Well, if they had mass you would see some effects. It would modify Coulomb’s law, which experiments didn’t detect. It would affect the galactic plasma, which experiments didn’t detect. So we know that the mass of the photon has to be less than 1×10−18 eV/c2 because if it were greater, we would have detected those effects. That is: we can’t measure “mass is zero” very well. Absence of mass is not mass of absence.

The question “is the mass zero?” has an exact no answer or non-exact less-than-this yes answer. But this has nothing to do with the value zero itself. Any value on a continuous scale (such as length, volume, weight, energy, temperature, stupidity, and so on) can only be measured within a finite precision. But we still can rule out a particular exact number. For example, I may not know the precise length of my right arm, but I do not that it’s not 3 meters precisely. I know because I can’t get a soda from the kitchen fridge when I am watching TV in the living room.

Consider another question: “do you have biological children?” If you are female, that is easily verifiable: if you didn’t notice, you didn’t have any. If you are male, and you think you have children, you can do a paternity test which may lead you to a conclusive yes. But to answer no conclusively, performing a paternity test on the whole earth population is not a good strategy: you may get a lot of false positives and may get stuck with a son 40 years older than you. Also note that if the first million people didn’t test positive, that would not be enough evidence to conclude you don’t have any children. So, for the no answer, you need an altogether different strategy. You should retrace your steps and maybe make a few phone calls. Good luck!

Once you realize that different answers may warrant different procedures, you may also realize that, for some questions, only a procedure for one side may exist. Will this complicated calculation I just started on my computer terminate? If it eventually does, then yes. Otherwise, beats me! Turing says you can’t know that in general.

So, if we wanted to be precise, we should say “the negation of an experimentally verifiable statement is not necessarily an experimentally verifiable statement”. See the problem now? It should be really really clear: that’s not at all catchy! How can this idea be communicated in these modern times, where the attention span is… Oooohhh… such a cute kitty! What was I saying? Oh, whatever…