The Order of Rovelli's Time – does time exist?

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What is time? Does it even exist? In this paper I will discuss the three main phases of Carlo Rovelli's philosophy of time, and I will conclude with an analysis of some of the criticism levelled against his view.

1. The End of Time
2. Time doesn't exist?!
3. Time is subjective
4. We Need More Time

1. The End of Time

The first part of Rovelli's narrative is a stepwise demolition of the traditional view of time. This traditional view is due to Newton, who viewed time as an objective (ie. the same for everyone) quantity that is needed to describe change, but which is itself in no way influenced by this change. Newton's time has a specific direction, which means that there is an objective difference between past and future, a difference that is the same for all observers.

Rovelli shows how little of this traditional view is left in modern physics. Relativity theory tells us that clocks tick at different rates in different places; thermodynamics shows us that the direction of time depends on our perspective (so it is not objective) and that there is no good reason to believe that time is anything more than merely change (I'll explain this in the following paragraphs).

Finally, Rovelli acquaints us with his relational interpretation of quantum mechanics. For his central claim, however, his interpretation of quantum mechanics is not essential, so I will not treat it in this paper.

1. Time doesn't exist?!

Rovelli is often portrayed as making the grand claim that *time does not exist*. But what does that even mean? We can illustrate Rovelli's claim in a simple example: say we use a clock to keep track of a runner in a race. We are used to thinking about such a situation as follows: To measure the change in position of the runner we use the parameter 'time', and changes in the time-parameter are described in terms of the changing positions of the hands of the clock. In such a way the changes in the clock can be used to measure the change in position of the runner with the help of the parameter 'time'. The physical description we end up with has three ingredients: the runner, the clock, and the parameter 'time'.

This sounds pretty obvious, but there is a different way of looking at the situation. Instead of expressing both the change in position of the runner and the changing positions of the hands of the clock in terms of the variable 'time', we could choose to describe the changes in the runner in terms of changes in the clock, and the other way around, the changes in the clock in terms of changes in the runner. In that way we don't need the time-variable anymore! Our alternative description has only two ingredients: the runner and the clock.

That's the idea behind Rovelli's claim. But the alert reader will have noticed that the conclusion we just reached (we don't *need* time) does not necessarily imply that Rovelli's claim is justified (there *is* no time). Although the phrase "time doesn't exist" can be heard in many interviews

Rovelli gives, the claim he actually makes in his book "The Order of Time" is more subtle. He writes: *time does not exist as a fundamental entity.* There is change; we see change all around us. But that's all there is to it. There isn't some fundamental entity or parameter underlying or describing this change.

We might rest here, and either agree or disagree with Rovelli that we have no need of a variable time and that therefore time doesn't exist as a fundamental entity. Something keeps nagging though, for what does 'fundamental' mean? Within the community of philosophers of science there is no consensus about this. Scientific articles about 'fundamentality' appear regularly, and in May 2018 there was even a conference in Geneva devoted solely to the topic. Sadly, no consensus was reached in the course of this conference (Prof. Vallia Allori; personal correspondence).

From what Rovelli writes I get the idea that what he means is that an entity is fundamental in the context of physics if it is a necessary element of physics. Since we don't need 'time' for the description of physical situations (as the example of the runner and the clock shows), it is not a fundamental element of physics. In his book Rovelli describes the *Wheeler-de-Wit equation*, an equation central to any attempt at unifying quantum theory with relativity. This equation is independent of time – a fact that serves as the main motivation for Rovelli to explain how it is possible that change happens in a universe devoid of time.

2. Time is subjective

According to Rovelli, we live in a world in which time doesn't exist as a fundamental entity. In the third phase of his argumentation, Rovelli shows us what the role is of change in a world without time, and how our experience of time emerges from that change.

The laws that govern the motion of particles – the laws of Newton – are time-symmetric. Were we to make a movie of two colliding particles (or billiard balls), then it doesn't matter whether we play the movie from beginning to end or the other way around (starting at the end and going to the beginning). Both movies represent the same collision, and neither of the two movies seem odd to us. What is considered 'past' and what 'future' depends on how we watch the movie: It seems as if nature itself has no preferred direction. The laws of motion are the same whether we play the movie from beginning to end or in reverse.

Then where does our feeling come from that time has a specific direction? We all know that ice melts and hot tea cools down; to see those processes in reverse would be odd indeed! In these processes there is clearly a direction – a direction that everybody will agree on: it is the direction in which the arrow of time points. Most phenomena in nature clearly follow the arrow of time: the smell of a rose spreading through the entire house (it won't just stay in one room), milk diffusing when poured into a cup of tea (it won't stay on or near the spoon), etc, etc. What do all these phenomena have in common? They show that nature is inclined to flow to increasingly chaotic (and therefore more probable) states.

This statement needs some unpacking. What do we mean by chaotic? And why are states which are more chaotic also more probable? To answer these two questions, we must introduce the distinction between two types of physical states: *microstates* and *macrostates*. Microstates are not (as the term might suggest) states of very small systems, but they are states *described in terms of microscopic constituents*. Think, for example, of a certain volume of gas. A *microstate* of the gas would be a description in terms of the positions and velocities of all the particles of which the gas consists. Such a description lies beyond the reach of any human endeavour (as the number of particles in gasses are typically in the order of 10^{23}), so physicists resort to describing the *macrostate* of the gas: a description in terms of *macroscopic* quantities, such as temperature, volume and pressure.

Any one macrostate will be associated with many microstates. To see why, consider again the box with gas: often it doesn't matter for the temperature or the pressure (the macroscopic quantities) if some particle A is on the right and another particle B on the left or vice versa. A-right&B-left and B-right&A-left are different microstates, both of which manifest themselves as the same macrostate. *Chaos* measures this: a macrostate is more chaotic if it is associated with more microstates. We can now understand why more chaotic states are more probable: due to the random motion of particles (assuming nonzero temperature) any physical system continually flows from one microstate to another. Macrostates that have more microstates associated with them will be 'visited' more often. Random thermal motion assures that more chaotic states are more probable.

We now have our arrow of time, and it has a clear direction: that of increasing chaos (or *entropy*, as physicists call it). But Rovelli argues that in gaining a clear direction (by looking at macrostates), we have lost objectivity. Rovelli argues as follows. A description in terms of macroscopic variables represents a choice. We mentioned temperature, volume and pressure as possible macroscopic variables, but there are many more choices. In fact, there is an infinity of choices (mass, colour, location, *you name it*). The characterisation of a macrostate presupposes a particular coarse-graining – a bit like representing the physical system at a certain resolution (you necessarily lose information). The direction in which chaos (entropy) increases depends on our definition of chaos, which in turn depends on our choice of macroscopic variables. The direction of the arrow of time, we conclude, depends on our perspective!

3. We Need More Time

So what do we make of this? Some philosophers of science that are very critical of Rovelli are convinced that there must be an objective arrow of time that can be agreed upon by everyone. Arguing that the arrow of time is dependent on our perspective isn't necessarily *wrong*, they say, but it defeats the whole purpose of doing science! It is the job of scientists to find out as much as they can about the objective world – the world that exists independently of us. If Rovelli argues that objective time doesn't exist and that the time we perceive is subjective, then what Rovelli's argument shows, according to his critics, is that science isn't doing its job properly. If the concept of time as it is used in modern physics is indeed subjective, then we haven't found the real thing yet: we need more time (try to sell *that* in an interview!).

It seems to me that the reasoning above, *"'real' time is objective; the time we perceive is subjective; so the time we perceive isn't 'real' time"*, is perfectly reasonable. It also has little to do with Rovelli's stance that time is subjective. It is about the starting point of Rovelli's analysis, not about the analysis itself. If you are dogmatic in not wanting to let go of the concept of objective time, then Rovelli's argument can't force you.

Is there nothing that can be said against the *content* of Rovelli's analysis? Is there really no hope of retaining the idea of objective time without resorting to dogmatism? I think there is. Let us return to the context of the definition of chaos (entropy). Rovelli argues that characterising macrostates is necessarily a subjective affair (this is important for Rovelli, because the subjectivity of time depends on it). But he cannot prove that there is not a way to objectively characterise macrostates. He claims that the subjectivity of the characterisation lies in the choice of macroscopic variables, but that presupposes that there isn't some set of *preferred variables*. If there are such preferred variables then the choice of variables wouldn't be different for different observers anymore, because all of them would choose the same variables – what was a subjective choice turns out to be objective. It is the task of the scientist to find out which these preferred variables are, because they describe real, objective time. Science is saved. Or so the critics might argue.