Gravity, time and motion

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The meaning of time in Physics is still matter of debate. Associated to this unsettled definition is the ignorance on whether the world is a 3-dimensional one that evolves with time or a 4-dimensional spatiotemporally extended object. This question relates to the standard mathematical framework of special relativity as well as to the quantization of gravity, evidencing the importance of it.

Newton took time as an independent existent. Einstein adopted spacetime, assuming that time was a dimension of the same kind as the three spatial ones. More recently, in the effort to quantize gravity, other ways of dealing with time have emerged, including shape dynamics (Barbour 1994, 2000; Gomes, Gryb & Koslowski 2011), a gravity theory that completely dismisses time. Notwithstanding, time is a concept - or, according to many, a real object (Smolin 2013) - that perhaps will never cease to be used (Gryb & Thébault 2016).

In this work we investigate the concept of time within the context of how physicists use it, based on an operational definition. We analyze the fundamentals of a physical clock, C, relating the time measure that it yields with the measurement of distances in space. Necessarily the knowledge of time depends on the knowledge of the movement of things (Augustine 1991), which happens in 3-space.

In this approach time primarily plays the role of a parameter whose values are obtained by measurements of a dynamical variable of a clock, which in turn can be considered a monotonically perfect clock: for some choice of initial state, its observed values increase monotonically, a needed characteristic for a parameter that allows the description of evolution. The use of dynamical variables to describe time apparently has limitations in quantum theory (Unruh & Wald 1989), so we restrict ourselves to classical ones.

Since the dynamical variable that yields time is a measure of distance, speed is not obtained by dividing an infinitesimal displacement by an infinitesimal time but by another displacement. Therefore, dynamics establishes correlations between displacements instead of between displacements and time.

The displacements that result from the clock's readings are uniquely related to values of the parameter "time", t, which is a tool for ordering events related to an observed system S.

The fact that the ordering parameter t relates physically to a system (C) other than the focus of the observation (S) implies that the spacetime metric contains elements of two distinct physical

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systems that may or may not be physically correlated. We discuss the implications of this fact to gravity in the context of general relativity.

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