Gravity's Time

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Remembering My Grandfather,

Who Taught Me How to Read Time

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Preface

This book is a mission to give gravity its due. There is supposedly a complete theory of gravity of which we celebrated the centenary year in 2016. Einstein's General Theory of Relativity (GTR) could very well have been the last word on gravity at our familiar scales, but for the fact that the theory was ahead of the times, taking premature birth. Like its predecessor – the Special Theory of Relativity (STR) – it is built on the basis of an *empty space*, with negligible matter content, as its fundamental premise. The characteristic feature of the STR, stated as its fundamental postulate, is the invariance of the relative velocity of light in any inertial frame. Its most notable physical effect is time dilation – the slowing down of the rate of clocks in relative motion. In addition, the GTR has the gravitational time dilation; clocks tick slower in a gravitational field. The physical effects due to gravity are calculated in the GTR with matter added to the pre-existing empty space. If one thinks hard enough, one can easily see that time never could exist in pure empty space. While one may imagine empty space in our fertile mind-space, clocks and time do not exist without matter. What we call time is factually the change in the physical state of some matter, in all cases imaginable. Time cannot be separated from matter, and matter without any evolution of its physical state cannot mark time. This change could be a simple motion of matter relative to another piece of matter, but some change in the physical state of being is essential to mark time. Time is material embedding in space. So, *empty space is timeless*.

Yet, one may argue that this is not a serious gap in our theories because we can assume that there is just enough matter to mark our time and that should not make any difference to the theory itself. Nothing could be farther from the fact and truth.

Both the Special Theory of Relativity and the General Theory of Relativity were completed and indeed accepted as plausibly the correct theories well before we knew anything significant about the matter around us in the Universe. Therefore, *the factual gravity of the vast amounts of matter in the matter-filled Universe is absent in these theories*. These theories took birth, and grew, when we remained ignorant about the matter content of the vast Universe. The result is that we ended up with a running cart with no horse to spot.

Special Relativity's clocks and time are modifiable but that has nothing whatsoever to do with gravity, or with any physical interaction. Special Relativity's clocks in *relative motion* change their rates without any physical reason. In contrast, General Relativity predicted the relative time dilation for clocks in different gravitational potentials. Yet, the theory missed the largest of gravitational potential we experience – the cosmic gravitational potential itself! As constructed, the GTR is operative in this Universe, in the presence of the cosmic matter, and yet the theory ignores cosmic gravity in its structure. A moving clock in the matter-filled space will surely experience a different potential compared to a stationary clock, unlike in empty space. The effects are large, if one bothers to calculate. Stated differently, if the theories of motion and gravity were formulated after the vast Universe and its contents became visible to us through the mighty telescopes that became operational after 1920, the history of physics would have been very different, and our physics would have been closer to truth. So, either we have made a big error and all motional effects are indeed gravitational, involving all cosmic matter, or we have to assert that the enormous amount of cosmic matter we observe with our large telescopes has no gravity. The choice is obvious.

The correct choice brings with it a revolutionary revision of our understanding of time. If cosmic gravity is the determining factor, then the cosmic frame is also a master preferred frame. It makes a difference whether one is moving relative to the cosmic matter or staying at rest. Therefore, *the relative velocities between two clocks could not be the criterion for deciding time dilations – it has to be the velocity relative to the cosmic frame*. We are, of course, back to the absolute space and time that existed in our physics and philosophy. The radical change in the physical paradigm is obvious. It is easy

to verify that all empirical results are not only consistent with this choice, but also are demanded by many a factual evidence. There is more than enough evidence in clock data, including the GPS, to show that what is relevant is not the velocity relative to the observer's rest frame, but the velocity relative to the cosmic frame. The navigational aids in the smart phones we carry are 'pocket proofs' that the prevailing theories of time need a drastic modification.

We will see that in fact there is an absolute clock synchronized all over the Universe. The temperature of the cosmic microwave background radiation is the same everywhere to a part in million or better, once the known small fluctuations are averaged out. This temperature is monotonically decreasing, providing us with the absolute 'cosmic clock'. It selects out one unique sequence of time slices in the entire Universe; then the general coordinate invariance that is one of the pillars of General Relativity is broken in the real Universe.

With this realization, Einstein's time goes out of the window of the vast edifice of physics. In fact, the situation in the physics of clocks, time, and relativity is more fluid than anybody could have suspected. The subtlety of the important issue of synchronizing clocks at different locations, foreseen and analyzed by Poincaré, became a fatal misinterpretation in the STR. This single crucial error, uncorrected despite an early warning critique by the philosopher Henri Bergson, remained with this theory and its history, forcing experimenters and GPS scientists to defend repeated anomalies with poor logic. Identifying cosmic gravity as the sole reason for the relativistic modification of time puts an end to a century of embarrassment of defending the inadequate physical theory. There is a special class of frames that are at rest relative to the cosmic matter, and all other frames see a matter current proportional to their velocity and hence a spatial anisotropy. Lorentz invariance, being violated by the real Universe, cannot be the basis of correct physics in spite of its accidental success, because most considerations depend only on the second-order part of the transformations (time dilation and length contraction) that are also part of the relativity theories with a preferred frame (like the ether, if one remembers the Lorentz–Poincaré theory).

With the absolute time and space back in the structure of physics, and with the current theory of relativity shown as inadequate, we are discussing time in a new paradigm. The gravitational paradigm of relativity correctly acknowledges the reality of cosmic gravity and incorporates it in the new theory of Cosmic Relativity. We do not discuss in this book all the aspects of the modified theory of relativity that I have developed in detail, except the connections relevant and essential for the discussion of time. The complete theory of Cosmic Relativity, its experimental support, and the induced modification of General Relativity are discussed in another monograph and in numerous papers. Cosmic Relativity is fully consistent with all known experimental evidence and it provides the most accurate description of the motional modification of time.

Time is gravity's tracker and faithful shadow. Once the frequency of an oscillator is specified, its phase is identical to time. But 'frequency' is akin to the energy in the quantum regime, and energy and mass are the sources of gravity. Energy being the 'charge' of gravity, time is affected by gravity in a universal way. The consistency circle is completed in Cosmic Relativity.

This book is not a discussion on the general nature of time within physics, or on the philosophical questions concerning time. Yet, we will touch on some relevant aspects briefly, when needed for clarity. These clarifications will have to necessarily be limited to the nature of the physical time.

It is high time that cosmic gravity got its rightful due as the determining factor for dynamics, relativity, and as the master of time. After centuries of search, we have mature and ample empirical evidence, all very transparent and direct, to guide and convince us about the true relation between cosmic gravity and TIME, and through that, about the intimate relation between the vast cosmos and us. We can now understand time in its true physical sense and completeness.

IT IS GRAVITY'S TIME.

Mumbai and Paris
December 2021

Acknowledgments

A monograph cannot just take its birth, with only its author in a role of creation. It needs an environment of both intellectual and emotional richness. In that I did not lack, because of the many colleagues and friends at the Tata Institute of Fundamental Research, Mumbai, where I worked ever since my graduate days, and in other laboratories where I was a frequent visitor. Looking back, it is wonderful to see that the whole of India, and beyond, was my land of activity in physics, and I must have gained plenty of wisdom from the numerous conversations on physics, art, and philosophy, without always realizing their influences.

As an unforgettable representative of the spirit of free mind and inquiry, I want to remember 'Rad', who was engaged in a conversation with me on some of the topics discussed in this book. I miss Prof. V. Radhakrishnan and the help I would have received from him in advancing true reasoned science. This book does not have a foreword because he is no more with us to write it.

My parents and my sister Karthika, keen observers of the progress of my work in fundamental physics for years, and my brother Hari, with his unconditional trust, have been providing the kind of support only family can.

Martine Armand was the constant companion all throughout the preparation, writing, arranging, and completing of this work. She did extensive scrutiny of the structure and presentation, and brought the final result in a vastly improved form.

Arvind Kanswal and the editorial team diligently ensured the progress of the book.

Finally, I thank my patient publishers, Stanford Chong and Jenny Rompas, who were very generous with time!

"*This book is a remarkable step in understanding the connection between time and gravity. Einstein's Special Theory of Relativity and General Theory of Relativity have been so successful for hundred years that their shadow has slowed down the development of physics. When those theories were developed, there was minimal understanding of the factual space and thought experiments were used. Professor Unnikrishnan has pointed out that the huge potential of the mass of the whole space is necessary to take into account in studies of local phenomena.*"

Dr. Heikki Sipilä
Finnish Academy of Technology, Finland

This book is unique and exceptional in dealing with the notion of physical time rigorously, both logically and empirically. The central theme is the intimate relation between physical time and cosmic gravity. It establishes and explains, in an accessible manner, the one crucial physical fact that has been missed in the development of modern physics—that the enormous gravity of the matter and energy in the Universe is the controller and cause of the relativistic time. The material in the book is accurate and free of the ambiguities in the discussion of time and its modifications (dilation), synchronization of clocks, and simultaneity. The contents go beyond the current theories of relativity that fail to incorporate the cosmic gravity in their structure. The discussion of clocks in satellite navigational systems (like the GPS) is the most complete and accurate. The book offers several new insights, and it is the only available treatise on the complete physical truth about time. The contents are addressed to a wide range of readers, from general readers and students to experienced researchers, and appeal well also to philosophers and historians of physics. This book has the enabling quality to deal with difficult questions about physical time, with unprecedented clarity and without paradoxes.

C. S. Unnikrishnan is a professor of physics at the Tata Institute of Fundamental Research (TIFR), Mumbai, India. His research interests are fundamental issues in gravity and quantum physics, and novel metrology. He was a visiting scientist at the Kastler-Brossel Laboratory, École Normale Supérieure, Paris. The first Bose-Einstein condensate in India was produced in his laboratory at TIFR. Prof. Unnikrishnan's major contribution is the paradigm of Cosmic Relativity, a theory of relativity and dynamics based on the factual gravity of the matter in the Universe, supported by many experimental results. Recently, he formulated a completion of Hamilton's action mechanics to a universal mechanics, solving the foundational problems of quantum mechanics. Prof. Unnikrishnan is a proposer-member of the LIGO-India project, for a Laser Interferometer Gravitational-Wave Observatory in India, and a member of the LIGO Scientific Collaboration that detected the gravitational waves. His other interests are music and films, especially the structure and process of their creation.

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