Paper Title: On the evolution of the concept of time and its implication for modern cosmology
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Abstract:
From the ancient Greeks, the concept of time has evolved over a period of more than two thousand years. With the emergence of the individual sciences, the problem has shifted from philosophy towards the natural sciences. Physics, as the basis of fundamental science, plays an essential role. At the beginning of the last century, the concept of time was revolutionized by Einstein ´s Theory of Relativity. What are the logical connections of the modern concept of time to the ancient philosophy?

I compare the ideas of Aristotle on time with those in post Einsteinian physics and shall argue that this comparison suggests an interesting interpretation in modern cosmology.

Biography:

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Born in Vienna, his education includes elementary school Vienna and Ascona (Switzerland), secondary education Caracas, Venezuela and Barbados, PhD in Physics and Mathematics, University of Vienna (1967). He was a research fellow at the “International Centre for Theoretical Physic”, Trieste, Italy (1968-69) and lecturer at the “Scuola Internationale Superiore di Studi Avanzanti in Trieste”(SISSA), Trieste, Italy (1981-86). He has been an Assistant (1974), associate (1980) full Professor (2000) at the University of Vienna. He is director of the Institute for theoretical Physics, University of Vienna(1984-86, 1990-92) and head of the advisory board to the *European Forum Alpbach* (2001-). His scientific publication are on gravitational physics, cosmology and classical field theory. His books include: "*Albert Einstein; his Influence on Physics, Philosophy and Politics*", P.C Aichelburg u. R.U.Sexl, Vieweg (1979), translations German and Japanese; *„Evolution, Entwicklungsprinzipien und menschliches Selbstverständnis in einer sich verwandelden Welt“,* Hrg. P.C. Aichelburg u. R. Kögerler, Verl. Niederösterr. Pressehaus (1979); and "*Zeit im Wandel der Zeit*", P.C.Aichelburg Hrg., Vieweg (1988).

Paper Text:

WHAT IS TIME?

What therefore is time asks St. Augustine in the 4th century and gives himself the famous answer [1]:

“Provided that no one ask me, I know. If I want to explain to an enquirer, I do not know”

Aristotle in his work thoroughly analyses the concept of time. He speaks about three fundamental problems in relation to time. Problems which after him philosophers addressed again and again. These are:

i) the existence of time
ii) the connection of time and change
iii) the problem of continuity

TIME AND CHANGE:
Aristotle ties time to movement or change and tries to find out what in a movement is the time. He argues that time manifest itself in the change of things but the change itself is not time[2]:

"So time is either change or some aspect of change; and since it is not change, it must be some aspect of change"
and
" ...not only we measure the movement by the time, but also the time by the movement, because they define each other"

At first sight this arguments seems of little use: that we measure movement with the aid of time is well known e.g. when measuring speed. Also we record time in terms of movement. The change of the hands of a clock tells us the elapsed time. Aristotle is of course aware of his circular argument. What is then the change that determines time? He argues that there is slow and fast movement but time is the same. The main idea of Aristotle consist in singling out a concrete "bounded" motion [3].

"Now there is locomotion, and as a kind of locomotion, ***circular*** *motion, and since each thing is counted by one thing of the same kind, and therefore time too by some definite time, and since, as we said, time is measured by change and change by time…then uniform motion is most of all measure…"*

But which circular motion [4]?

"*This is why time is thought to be motion of the (celestial) sphere, because the other changes are measured by this one, and time by this change."*

Aristotle introduces 53 heavenly spheres to explain the motion of the celestial bodies. For him time is defined by the motion of these spheres. Especially by the fix-stars. Without this time can not be measured and therefore there is no time. In a generalized sense one could say that it is the motion of the bodies in the universe determine time.

Before I contrast these ideas with the modern concept of time in cosmology, let me recall very briefly a few landmarks in the development of the concept of time. The above mention St. Augustine criticises Aristotle in his "Confessions" by the following intuitive example [5]:

"I have heard a learned person say that the movement of the sun, moon, and stars in themselves constitute time. Why should time consist rather of movement of all physical objects? If the heavenly bodies were to cease and a potters wheel were revolving, would there be no time…."

He questions the concept of defining time by the motion of the stars. He is even more explicit in his statement [6]:

"*Let no one tell me then that time is the movement of heavenly bodies. At a mans prayer the sun stood still, so that the battle could be carried through to victory (Josh.10:12ff) the sun stopped but time went on"*

Augustine refers here to the battle of Joshua against the Amorite in the old testament.

ABSOLUTE TIME

More than a thousand year after this, Isaac Newton takes up the criticism of Augustine and postulates the existence of an absolute time He writes in his *"Philosophiae naturalis .principia mathmatica"* [7]:

"Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external.."

But admits that this absolute time might be impossible to measure:

„It may bet hat there is no thing as an equable motion, whereby time may be accurately measured. All motion may be accelerated and retarded, but the flow of absolute time is not liable to change."

Besides the absolute time Newton introduces the concept of absolute space with respect to which motion and rest may be defined unambiguously. The Austrian philosopher and physicist Ernst Mach takes up the issue of time in his treatise on "*Mechanik, in ihrer Entwicklung , historisch kritisch dargestellt"* .Mach argues that Newton does not comply with his own idea to only study the factual [8]:

"Diese absolute Zeit kann an gar keiner Bewegung abgemessen werden, sie hat also gar keinen praktischen und auch keinen wissenschaftlichen Wert...Wir sind ganz außerstande, die Veränderung der Dinge an der Zeit zu messen. Die Zeit ist vielmehr eine Abstraktion, zu der wir durch die Veränderung der Dinge gelangen, weil wir auf kein bestimmtes Maß angewiesen sind, da eben alle untereinander zusammenhängen".

"This absolute time can not be read off from any motion, therefore has no practical and scientifically value ...we are completely incapable to measure the change of objects with respect to time. Time is an abstraction to which we arrive at by the change of objects because we do not rely on a concrete measure since all are interconnected."

Mach wants to stress that we do not need to single out a certain motion for measuring time, but instate, because its "interconnection" we arrive to a consistent abstraction, which we denote time. Following Mach, absolute time is a useless construct. In contrast, the interplay of all the components in the universe could lead to a universal time.

FROM ABSOLUTE TO RELATIVE TIME

Despite of this criticism, for more than 200 years Newtons concept of absolute time served as a fundament for describing physical aspects of nature. Especially in classical celestial mechanics, like the description of the planetary orbits, the prediction of solar and moon eclipses and for describing gravitationally bounded system in general, observations were in excellent agreement with Newton theory of gravity. However, in the beginning of the last century a radical revision of the classical concept of time was initiated by Lorentz, Poincare and mainly Einstein. Were in the past time and space independent entities, the concept of spacetime emerged. Three years after Einstein put forward his special theory of relativity, Hermann Minkowski at the meeting of the "Versammlung Deutscher Naturforscher und Ärzte" in 1908, began his contribution on "Space and Time" with the sentence [9]:

"Die Anschauung über Raum und Zeit, die ich Ihnen entwickeln möchte, sind auf experimentell-physikalischem Boden erwachsen. Darin liegt ihre Stärke. Die Tendenz ist eine radikale. Von Stund an sollen Raum und Zeit für sich völlig zu Schatten herabsinken und nur noch eine Art Union der beiden soll Selbständigkeit bewahren."

„The view of space and time which I wish to lay before you have sprung from the soil of experimental physics, and therein lies their strength. They are radical. Henceforth space itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality"

The starting point for Einstein was to analyse what simultaneity of events means. In 1905 he writes[10]:

"Wir haben zu berücksichtigen, dass alle Urteile, in welchen die Zeit eine Rolle spielt, immer Urteile über gleichzeitige Ereignisse sind".

„We have to consider that all our judgments in which time plays a role refer to simultaneous events."

What do we mean when we say two events at distant places are simultaneous? And the related question: How to synchronise distant clocks? Intuitively we seem to know what simultaneous means. Events that we observe at the same moment. But this in fact is not precise, because any signal propagates at finites speed. Even light from distance objects reaches us later that from nearby ones. We therefore see distant objects in an earlier state. This does not show up in every day life, but is a well known fact in astronomy. The farther we look into the universe the more we see into the past. Our visual and therefore reception in general, does not give a simultaneous picture of the outside world. One could argue that the travel time of signals can be taking into account and thereby construct the simultaneity. But it is at this point were relativity sets in. While in the Newtonian view one would arrive at a unique construction of simultaneity, because of the existence of an absolute time, this fails for Einsteins theory. Following Einstein, simultaneity is not unique but depends on the state of motion of the observer. Different observers would construct different simultaneous images of the state of the world.

The mathematician Kurt Gödel wrote in a short essay with the title "A Remark about the Relationship between the Relativity Theory and the Idealistic Philosophy" " on the philosophical implications of this new structure of spacetime [11]:

"...it seems, that one an unequivocal proof for the view of those philosophers who, like Parmenides, Kant and the modern idealists, deny the objectivity of change and consider change as an illusion or as appearance due to our special mode of perception"

FROM RELATIVE TO DYNAMICAL TIME

In the theory of Special Relativity simultaneity loses its absolute meaning and with it the concept of an absolute time. General Relativity goes a step further: Time is not only influenced by motion but also matter in the universe. The rate of clocks slow down in the neighbourhood of large masses. Both, the influence of motion and gravitational effect are relevant e.g. when synchronising the clocks in satellites for the global positioning systems (GPS). These satellites orbit the earth at an altitude of about 20.000km. Not taking into account the relativistic effects would make the system in a few minutes useless for detecting the position.

The geometry of spacetime and with it the elapse of time is influenced by the distribution of matter and therefore becomes dynamical. Every history of a body has its "proper" time in dependence of his motion and distribution of the other bodies (more generally mass and energy) in the universe.

FROM DYNAMICAL TO COSMOLOGICAL TIME

The theory of General Relativity has its most far reaching implication for physics and philosophy when applied to the cosmos at large. What is of interest here is the question, how the interaction between matter and geometry influence the concept of time. Einstein's equations imply that there can not be a static universe. Einstein himself tried to circumvent this consequence by adding the so called cosmological constant and thus modifying his original equations. But in 1929 the astronomer Edwin Hubble concluded from observations that all galaxies recede with a velocity proportional to its distance from us. Today we know that on very large scales matter is distributed uniformly. Thus the motion of galaxies can be interpreted as an overall expansion of the universe. But it is this overall expansion which allows to define a universal reference system tied to the flow matter. All observers moving with this Hubble flow have the same proper time, which then defines a universal time. It is this time when we say that since the big bang about 14 billions years have elapsed.

This cosmological time brings us back to the time concept of Aristotle who defined time to be the motion of the heavenly spheres. In modern cosmology time is given by the overall motion of the matter in the universe. But the analogy goes deeper. Aristotle says the singled out motion is time i.e. without the movement of the celestial spheres there would be no time. Relativity theory ties the geometry of spacetime with matter and energy. In cosmology matter determines the spacetime geometry in the large and therefore time.

References:

[1] Saint Augustine, Confessions; transl. H. Chadwick, Oxford Univ. Press 1991,p230

[2] Aristotle´s Physics; transl. by E. Hussley (Calderon Press, Oxford, N.Y.), p.43

[3] ibid p. 53

[4] ibid p. 53

[5] Saint Augustine, Confessions; transl. by H. Chadwick, Oxford Univ. Press 1991, p. 237

[6] ibid p. 238

[7] Newton I. *Philosophiae Naturalis Pricipia Mathematica (1967)* quotations from *Sir Isaac Newton´s mathematical Priciples of natural Philosophy and his System of the World F.* Cajori, Univ. of California Press; Berkeley (1962),pp 6-12

[8] Mach E., *Die Mechanik in ihrer Entwicklung, historisch-kritisch dargestellt,* F. A. Brockhaus, 6th ed., Leipzig 1908, p. 236

[9] Minkowski H., *Raum und Zeit ,*in H. A. Lorentz, A. Einstein und H. Minkowski, *Das Relativitätsprinzip,* Teubner, Leipzig 1913, 2ed printing 1915, p 56

[10] Einstein A., *Zur Elektrodynamik bewegter Körper,* Annalen der Physik Bd. 17, 1905, p. 891
[11] Gödel K. in *Albert Einstein: Philosopher-Scienist* Edt. P.A. Schilpp, Cambridge Univ. Press, London (1969*)*