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PHILOSOPHICAL COMMENTS ON KOZYREV'S THEORY OF TIME[1]

Ливадитис Д. **Философские комментарии к теории времени Козырева.** При обсуждении теории времени Козырева обычно уделяется мало места ее соотнесению с внешними положениями, особенно если дело касается философских проекций. Учитывая присущий теории инновационный и провоцирующий мысль характер, было бы полезно, как думается, представить ее на фоне других наиболее известных теорий времени, разработанных в физике. По этой причине в начале статьи дается краткий обзор таких теорий с упором на онтологию, причинность и структуру времени, вслед за чем производится сравнение с теорией Козырева. В завершение намечаются некоторые перспективы, которые могут, по мысли автора, помочь в разработке более надежного концептуального и математического основания дальнейшего развития козыревской концепции времени.

Kozyrev's theory of time is usually discussed with little outside references, especially as its philosophical implications are concerned. As much thought provoking and innovating as it is, it would be useful to present it in philosophical contrast with the other main theories of time that physics has presented us. For this reason, I first give a brief surveying of these other theories with emphasis on the ontology, causality and structure of time, and then a comparison is made with Kozyrev's own theory. Finally, some perspectives are given that I think may lead to a more secure conceptual and mathematical basis for further development of the Kozyrevean concept of time.

1. INTRODUCTION

It is well known to anyone familiar with N. A. Kozyrev's work that the main issue that occupied his scientific and intellectual life was the *Phenomenon of Time*. Kozyrev, belonging to the elite of scientists that move science a step further, created his own theory of time, frequently dubbed as *Causal Mechanics*. In this paper, after offering a brief overview of the main theories of time that physics has presented us from Newton till our days (since in most of these theories the con-

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cept of time is intrinsically connected to the concept of space we will mention the latter too), Kozyrev's own theory will be presented and commented in comparison with these other theories, primarily from a philosophical point of view.

In doing so, we will focus mainly on three subjects: the ontology of time, time and causality, and the structure of time.

2. NEWTONIAN TIME

Newton's concept of space and time is contained in his famous *Scholium* after the section of definitions (Newton, [1687] 1999). What we can infer with certainty from this, is that Newton believed in the reality of space and time, that is, he took them as entities in their own right: space and time are conceived as substances that form a substratum that underlies all physical processes. And since Newton believed in absolute motion, that is, a motion independent of a reference frame, space and time had to have a structure that would support such kind of motion. This structure is intrinsic, fixed and immutable. The immovable structure of space is that of an Euclidean three dimensional space E^3. Time, on the other, hand is characterized by a unique partition of events into simultaneity classes, in other words it is characterized by absolute simultaneity (without reference to any particular frame of reference). Between non-simultaneity events there is an absolute duration, i.e. the measurement of the time interval between such events is the same for all observers (Earman, 1989, chap. 1).

As causality is concerned it seems that Newton didn't support the idea of a universal causation, i.e. that every event must have a cause. A careful reading of the *Scholium* suggests that for Newton causes were forces or constraints that compel moving bodies to behave differently than they would have done without them. Any object not subjected to such causes will continue in its state of rest, or its uniform motion in a straight line. Clearly for such events there are no causes, at least as Newton thought of them (Collingwood, [1938] 1991).

Symmetry in causality appears twice in Newton's theory. Firstly, Newton's second order differential equations of motion are time symmetric: that means there is no way to tell between time running forwards to the future from time running backwards to the past. Future determines past in the same way that past determines future. We can specify the future state of a physical system and then use it in order to specify its past state. Secondly, the third law of Newton gives us a complete symmetry as to what actions (causes) and reactions (effects) are. Causality is therefore completely symmetric in Newton's theory.

Finally, a few words about Newton's theory of gravitation and its implications for causality. It is generally believed that Newtonian gravity is a force that acts instantaneously between all material objects, irrespective of their distance. So we might say that there is a synchronicity between cause and effect in that case. But as it is known, Newton thought that gravitation must be the effect of some subtle particles about which he said the famous *«hypotheses non fingo»* (*«I feign no hypotheses»*). Therefore one might think that Newton would have expected a more precise theory of gravitation to take the speed of these particles into account. In fact it was Paul Gerber who followed that line of thinking: assuming that gravitational influence travels at the speed of light he managed to derive exactly the equation which Einstein derived from the General Theory of Relativity, and that 17 years before Einstein, before even the discovery of the Special Theory of Relativity (Maudlin, 2002, chap. 1).

History of science tells us that Newton's ideas of absolute space and time were strongly opposed by Leibniz. Many believe that it was Leibnizs' criticism which led (through Mach) to Einstein's Special Theory of Relativity of which we will talk next.

3. MINKOWSKIAN TIME

In 1905 Einstein introduced a radically new theory that altered forever the way we think of space and time: the Special Theory of Relativity (STR). STR can be derived from the central postulate of the invariance of the speed of light: every ray of light in a vacuum has the same speed, $c = 3 \cdot 10^8\ m/s$, in all inertial frames of reference. As it is well known this has as consequence that the Galilean transformations expressing the transition between inertial frames in Newtonian mechanics give their place to Lorentz transformations. These new transformation laws have the following consequence for the structure of space and time:

1. There isn't anymore absolute simultaneity. Simultaneity is relative to a reference frame.

2. The spatial distance d between events does not remain invariant.

3. The time elapsed t between events is not invariant.

There is however a quantity which *is* left invariant (besides the speed of light). This is the so called spacetime interval $l = d^2 - t^2$ which is neither spatial nor temporal but a mixture of both. Since another central postulate of STR is that all inertial frames are equivalent, there isn't any «correct» (true for all observers) decomposition of the interval into spatial and temporal components. The only objective (frame independent) fact about the events is the magnitude of the spacetime interval that separates them (Dainton, 2001, p. 264). This is probably the thing that prompted Minkowski to open his famous lecture delivered at the 80th *Assembly of German Natural Scientists and Physicians* (September 21, 1908) with these words quoted since so often:

Henceforth, space by 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.

Minkowski's idea about how to construct such a spacetime was to build it based on the trajectories that light rays follow in the vacuum. The key notion is that of a *light cone*. If we consider a light source, light spreads from that source in all directions forming a spherical surface. As time passes, this spherical surface expands. If we use two dimensions instead of three to represent space, this all looks like a cone. Accordingly, we can represent all the light arriving at the source by the surface of a second cone, which extends backwards in time.

A time cone partitions spacetime in four regions. The points on the surface of the cone are those that can be connected by light rays traveling in vacuum and therefore are said to be «light-like» connected. The points outside the cone are known as «absolute elsewhere» and can be connected only by a signal traveling faster than light. These points are said to be «space-like» separated. Finally there are the points inside the cone that constitute the regions called «absolute past» and «absolute future». These points can be connected by signals traveling slower than light and they are said to be «time-like» connected. What is interesting from the point of view of causality is that if we accept that no physical influence can travel faster than light, only events that are time-like connected can be causally related.

But this much about the structure of STR spacetime and the causality it generates. What about the ontology? Well, it seems that STR supports the so called *static block conception* which advocates that all events are real, irrespective of their spacetime location (Dainton, 2001, chap. 17). Indeed, imagine that someone would hold that only the present is real and that the past and the future are unreal (the so called *presentism),* or even more liberally that present *and* past are real (the so called *growing block theory*), but not future. But according to STR there is no absolute simultaneity: what is present for me is considered as past or future at another observer's reference frame. There is no such thing as a *moving present*. What we experience as a flow of time from past to present and then to future is nothing but an illusion. The real state of the Universe as a space-time continuum is timeless. Borge's hero Dahlmann went on a journey south (=back in time) where all is there (Merell, 1991, p. 142).

4. EINSTEINIAN TIME

STR's limitations are obvious when one tries to incorporate in that theory Newton's gravitational theory. Newton's gravitational force between a pair of material bodies depends inversely on the square of their spatial distance. But as we have seen according to STR this distance will be different in the inertial frames of the bodies in question if these are in relative motion. As a result, observers on the two bodies will calculate a different magnitude of the gravitational force between them. Secondly, STR put a limit on gravitational influence's velocity when «traveling» from one body to the other.

Einstein started working feverously on this problem as early as 1907 and it wasn't until 10 years had passed that he came up with a solution: the General Theory of Relativity (GTR). The main idea was that of the *equivalence principle.* This takes two forms: Firstly, it says that the laws of physics take the same form in frames that are freely falling in gravitational fields as they do in inertial frames. Secondly, and perhaps more significantly, it basically says that there is no way of telling locally between gravitational effects and acceleration effects. All these led Einstein to the idea that gravity is not a force: it is just the bending of space and time caused by material objects in their vicinity. This matter-induced curvature is transmitted through spacetime at the speed of light. This has as immediate consequence a tremendously different picture of spacetime from that postulated by STR: according to GTR spacetime has a dynamic, not a static, structure: as the material bodies of the Universe induce curvature in spacetime, its overall shape changes as the result of their combined influence, and as the bodies move around, this shape continuously changes (Dainton, 2001, p. 289).

As ontology is concerned, it seems that GTR supports a substantival spacetime. The transfer of gravitational energy between gravitational waves and spacetime and the way that geometry of empty spacetime determines the motion of the bodies renders a relationalists approach at least problematic. But relationalists didn't say their last word: the revival of «the hole argument» in the 1980's by Stachel renewed the discussion. It seems that if one continues to support spacetime substantivalism then the hole argument compels one to accept also a radical indeterminism (Earman and Norton, 1987). But the issue isn't resolved yet and it seems that the substantivalist has some escape routes (e.g. *metrical essentialism*).

As time itself, it seems that there are models[1] of GTR that support a static view as well as a dynamic view. Dynamic friendly GTR models assume a partition of the spacetime in non-intersecting three dimensional hyperplanes that are orthogonal to the time-like geodesics. Each hyperplane represents the entirety of the Universe at given moment of time. The succession of these hyperplanes generates a consistent time-ordering, something like a cosmic time. Two possible pictures for dynamic time supporters are possible here. Dynamic presentists give us a picture of worldwide *cosmic time* that flows as a succession of thin hyperplanes, created and annihilated successively. On the other hand growing block theorists give us a picture of an expanding solid sphere growing as hyperplane is added to hyperplane (remember that for growing block theorists past as well as present is

[1] Any possible universe whose matter distribution and spacetime geometry conforms to Einstein's equations is said to be a model of GTR.

real so for them there is no annihilation of the hyperplanes) (Dainton, 2001, chap. 19).

As we mentioned though, there are also models of GTR friendly to the static block conception. Of course there can be here no global simultaneity: remember that in GTR inertial frames can be defined only locally. Perhaps the most interesting among these models are the so called *Godel worlds*. Godel found solutions of the Einstein equations that give rise to time-like paths which, when followed in a given direction, eventually lead back to same point. We are talking of course of the famous «closed time-like curves» (CTC's). In these curves time runs in a circle, so anyone who completes a trip around the circle will find himself where he started in time as well as in place. In such a world a time travel back in the past would be probable, something that gives rise to all sort of (apparently?) paradoxes concerning backward causation (see Thorne, 1994). Therefore in a Godel's world there is a complete destruction of the time order: apart from the fact that there are no global time slices, each of the events along a CTC is both earlier and later than all the others.

It has been argued against Godel worlds that the matter distribution in our Universe is such that rules out these models while it supports the dynamic models we saw earlier. But as Godel himself said (1949) it is not important if we live in CTCs-free Universe or not. What is important is the physical possibility of CTC's in our Universe. This indeed would render the structure of time something that can be altered by the mere rearranging of Universe's matter distribution.

Thus far we have examined spacetime large-scale theories. Let's see now what our best theory of our microcosm, Quantum Mechanics (QM), has to say about time.

5. QUANTUM TIME

As everything (!) with QM, time also can be a very confusing issue. A distinction should be made here which of course applies to all theories but which becomes particularly problematic in QM as we shall see. The distinction is between external and internal time (Hilgevoord, 2005). All physical theories (with the notable exception of GTR) are formulated relative to a *given* space-time background: these are the *external coordinates of space and time*. But connected with the specific physical systems are the position variables of the particles and the time variables of the clocks: these are *the internal spatial and time variables* which have to obey certain equations of motion. Specifically, internal time measures the evolution of a physical system. The main difference with classical and quantum mechanics is that while in QM the external space and time coordinates remain ordinary classical numbers, the dynamical variables of space and time have to be represented by quantum mechanical operators (or matrices in Heisenberg's formulation) like all other dynamical variables. This is indeed the case for internal space which is represented by a position observable with eigenvalues ranging over the whole real axis. The lack of an analogous operator for time became the «deep» problem of time in quantum mechanics. The famous footnote in Pauli's 1933 Encyclopaedia article deals exactly with this problem:

"In the older literature on quantum mechanics, we often find the operator equation $\widehat{H}\widehat{t}-\widehat{t}\widehat{H}=(\hbar/i)\bar{1}$... It is generally not possible, however, to construct a Hermitian operator (e.g. as a function of p and q) which satisfies this equation. This is so because, from the commutation relation written above, it follows that $\widehat{H}$ possesses continuously all eigenvalues from $-\infty$ to $+\infty$..., while on the other hand only discrete eigenvalues of $\widehat{H}$ can exist. *We, therefore, conclude that in principle we must deny the introduction of an operator t and the time t in wave mechanics must necessarily be considered as an ordinary number* ("c-*number*")." (Pauli, 1933, p. 140).

It has been argued though that time poses no fundamental problem for quantum mechanics (Hilgevoord, 2002) and that the representation of the dynamical variable of time as a quantum mechanical operator is possible. However, it turns out that neither position- nor time-operators are relativistically covariant concepts. Anyway, the issue is still very much controversial (see Muga et al., 2002).

But the troubles aren't over. It seems that in entangled states between quantum particles a quantum connection arises which defies the short of causation that STR asks for. We are talking of course of the so called EPR paradoxes. Roughly the situation is as follows: An atom emits a pair of photons which go off in opposite directions. What happens is that although the photons individually show no particular polarization, each member of the pair acts as if it has the same polarization as its partner. We say that the photons are *perfectly correlated*. Bell (1966) derived his famous inequalities concerning the possible constraints that these correlations satisfy *if* we accept that the observation carried out on one particle cannot influence the result of the observation carried out on the other, i.e. if we accept that our theory is local. It turns out that these inequalities are violated by the quantum mechanical predictions. Repeated experiments in the 70's and 80's, amongst them the famous Aspect experiment in France (Aspect et al., 1981) showed that quantum mechanics is right and Bell inequalities are wrong. It seems that no local theory can reproduce the results of QM. Somehow the particles remain interconnected. This quantum connection appears to be unaffected with distance and instantaneous. Naturally questions arise such as: is there a direct causal link between the two particles and if so does this superluminal causal influence discredit STR?

The literature on the subject is vast and much interpretation-dependent and we will confine ourselves to some very important conclusions drawn by Maudlin's (2002) exhaustive treatment of the subject.

– Violations of Bell's inequality do not *per se* imply the possibility of sending either energy or signals from one particle to the other. Furthermore, QM entails that energy and signals cannot be sent via the mechanism which produces the violation.

– Outcomes from observations on one particle *are* statistically dependent from those at the other, and this dependency cannot be accounted by common causes which lie in the past light cones of the measurement events.

– Bohm's theory and orthodox collapse theories can account for this causal link at the price of the abolishment of Lorentz invariance, one of the fundamental ontological claims of STR.

– Lorentz invariant theories may be developed which will account for the connection using explicit backwards causation but the onto logical implications of such theories are hard to understand.

– Many minds theory avoids collapse and retains locality, but runs completely opposite to common sense.

As Maudlin nicely puts it: «*choose your poison!*».

Finally, there are suggestions that there is after all a local explanation of this quantum connection in the framework of GTR. Abandoning the simply-connected topology of Minkowskian space-time, we might envision «wormholes» embedded in spacetime so that regions spacelike separated in the external space can be a short distance apart along a route traversing the wormhole (Holland, 1993, chap. 11). But these suggestions remain controversial as well.

6. KOZYREVEAN TIME

Reading Kozyrev's works (Kozyrev, 1991) one can easily understand that the main drive behind the theory he developed was his endeavour to provide an explanation for something that everybody knows to exist but seems not to be taken into account by scientific theories: the *direction of time*.

For example consider Minkowski spacetime which sometimes is said to embody the causal structure of the Universe. As we saw (see Section 3) STR formulated in this spacetime supports a static block conception of the time, where past, present and future all are real and exist together. But it is a fact of life that, evidently, everyone feels that he lives in the present, has memories of the past, and grows older as time passes by. It is such sort of *asymmetries* amongst the mental and material processes that exist *in* time, that make us think that there *is* after all a time direction. Kozyrev of course supported strongly such a view:

"The natural desire arises to introduce into the exact sciences the principles of natural sciences. In other words, the tendency is to attempt to introduce into theoretical mechanics the principle of causality and direction of time" (Kozyrev, 1963, p. 1).

Leaving aside asymmetries that can be refuted on the ground of psychological conventions or simply are considered as secondary (knowledge asymmetry, experience asymmetry, etc.), there seems to be two major asymmetries that pose serious difficulties to a static block theorist: entropic asymmetry and causal asymmetry.

According to the second law of thermodynamics, entropy in a closed system increases over time. Obviously there we have an asymmetry, expressed as a law of Nature, which is directly connected to time direction. But are the thermodynamical processes really irreversible? The first objection was formulated as early as 1889 by Poincar's *«recurrence theorem»,* which briefly stated that the particles in an isolated system will eventually (even after infinite time) return to a state very similar to their initial one. One of the founding fathers of thermodynamics, Boltzmann himself, took this objection very seriously, and suggested that what we think as «Universe» was in fact only a small part of a far greater whole which is really in equilibrium. So in our part of this whole, a local entropic increase may provide time with a direction (earlier = lower entropy, later = higher entropy), but the average entropy of this whole is neither decreasing nor increasing leaving time without direction.

A second objection to the entropy asymmetry argument is the following: Let's suppose that somehow the entropy in an isolated system is decreasing. Would that mean that the other asymmetries will reverse too? We, as humans, would we feel any difference? Dainton (2001) gives a nice example. Suppose that one half of the Atlantic Ocean becomes 20°C warmer than the other half, and as a result the entropy of the Atlantic decreases. Life on a ship would become much more difficult due to the extreme weather conditions but it would not start to run in reverse!

What about the causal asymmetry? It is a common belief that causes usually occur earlier than their effects. Doesn't this distinction between causes (earlier) and effects (later) give time a sense of direction? A first objection may come from theories as GTR where backward causation is a possibility at least in models with closed time-like curves (see Section 4). Simultaneous causation poses a similar problem. But suppose we don't accept neither backward nor simultaneous causation as real possibilities. Then a second, more serious, objection comes forth: unless causal theorists can distinguish between the events that consider as causes and the events that consider as effects, without appealing to the earlier-later distinction (that is to an already established time direction), then their argument runs circular. According to Hume the equations «cause = earlier event» and «effect = later event» are mere linguistic conventions. As Dainton (2001, p. 52) eloquently puts it: «To avoid the charge of triviality causal theorists must reject the Humean view, and provide a substantivalist account of *causal priority* (i.e. how causes differ from their effects) that does not appeal to *temporal priority* (i.e. it will not suffice to say that causes differ from their effects by occurring earlier than them)». And he concludes saying: «The only thing that is clear and relatively uncontroversial is that finding an objective and non-temporal difference between cause and effect is a far harder task than one might have imagined, and so a good many philosophers have concluded that there is no such difference» (Dainton, 2001, p. 53).

There comes Kozyrev's ingenuity. Having recognized all these difficulties, he builds causality not *within* time but *from* time. That is, time itself has the capacity to distinguish between causes and effects. It is time through its direction that creates causality, not the other way around. This seems to me to be the central postulate from a philosophical point of view of his whole theory. As Kozyrev formulated it in his own words:

"Time possesses a specific property of distinguishing causes form effects, which may be called directionality or course. This property determines the difference between the past and the future" (Kozyrev, 1963, p. 2).

Let's see closely how this is accomplished according to Kozyrev. In fact Kozyrev imagined an elementary cause-effect link which comprises two material points designating the cause and the effect separated by an «empty» spacetime point as he called it. «Empty» point means according to Kozyrev a point where there is no matter there, just a bare spacetime point. This «empty» point is very important since the conversion of the cause to an effect requires overcoming it. Elsewhere Kozyrev refers to it as the «...abyss, the transition through which can be realized only with the aid of time» (Kozyrev, 1963, p. 3). This point has a spatial coordinate δr and a temporal coordinate δt signifying the fact that causes and effects are always separated in space and in time. According to my reading, these two quantities, over which much ambiguity stills looms even among Kozyrev's followers (see Shikhobalov, 1996a), shouldn't really be thought as indicating «everyday» space and time intervals: they certainly are of a more abstract nature. The very word «abyss» used by Kozyrev points to that direction. As I understand it Kozyrev meant *St* to signify the absolute (positive) difference between the future and the past, the «world-arrow» as modern philosophers sometimes call it, while δr signifies more generally a direction in space. Someone would say that in an isotropic space as that of our Universe there are no differences in directions, but still we can find a difference between a right-handed coordinate system from a left handed coordinate system: in this case it may be suggested that conventionally a positive sing of δr would correspond to the former while a minus sign would correspond to the later. Both quantities therefore signify mostly abstract directions and do not take any particular values. In this regard the elementary cause-effect link shouldn't be thought as the «real» spacetime distance between cause and effect. It is less than physical and more of a philosophical (or metaphysical if you wish) kind of *link*. We tentatively therefore posit

$$\begin{aligned} &\delta r = \textit{direction in space} \equiv (\widehat{i}, \widehat{j}, \widehat{k}) \equiv + \\ &\text{for a right handed coordinate system,} \\ &\delta t \equiv \textit{future} - \textit{past} \equiv +, \end{aligned} \tag{1}$$

where δr is parameterized by the basis vectors of a Cartesian coordinate system $\widehat{i}, \widehat{j}, \widehat{k}$.

Through δr and δt a quantity of utmost importance for Kozyrev's theory is defined, the so called *course of time:*

$$c_2 = \delta r / \delta t. \tag{2}$$

According to the previous discussion, the course of time determines the transition rate from the cause to the effect in an elementary cause-effect link. It should be emphasized here again that the whole process doesn't just occur in time, but with the aid of time. So we can think of c_2 as the velocity of a time-energy field (I will comment more on that later). Since δr and δt refer to the «empty» spacetime point, c_2 shouldn't be dependent on any particular physical system but it should be thought of as a universal constant. Kozyrev indeed postulated the universality of c_2 and even went as far as to calculate it through experiments, finding:

$$|c_2| \approx 2200 \text{ km/s} \approx ac,$$

where α is the fine structure constant and c is the velocity of light in the vacuum. It should be emphasized again that c_2 was calculated through experiments and not through type (2) which serves more as a philosophical definition, according to what we said earlier about δr and δt.

Kozyrev now imagined a parity transformation, i.e. our world reflected in a mirror. As it is known parity transformation corresponds to a transformation from a right-handed coordinate system to a left-handed one. Therefore, according to (1) δ*r* will acquire a minus sign. If on the other hand δ*t* signifies the world arrow, the way people think that future is always «ahead» of their past, then in the mirror world too δ*t* has to keep the same sign, otherwise this would let to an absurdity. So we have

$$\delta r \equiv \left(\widehat{i}\ \widehat{j}\ \widehat{k}\right) \equiv + \xrightarrow[\textit{transformation}]{\textit{parity}} \delta r' \equiv \left(\widehat{i'}\ \widehat{j'}\ \widehat{k'}\right) \equiv - \,,$$

$$\delta t \equiv + \xrightarrow[\textit{transformation}]{\textit{parity}} \delta t' \equiv + \,,$$

where $\widehat{i'}, \widehat{j'}, \widehat{k'}$ are the basis vectors of the inverse axes. Then according to (2) the constant c_2 has to change its sing under the parity transformation which makes it a pseudoscalar rather than a scalar quantity. This gives us a clear distinction between the world-arrow δ*t,* the «apparent» direction of time, from the causal arrow represented by c_2, the «real» direction of time. While the distinction between these two arrows is usually used as an argument by modern philosophers to devaluate any relation between causal theory and the direction of time (see Daimon, 2001, p. 53–55), Kozyrev accomplishes with the same argument just the opposite, giving time a substance: «real» time appears as an energy-like field which offers its energy for the transformation of a cause to an effect while the «apparent time» is just the psychological notion of the time that people have in order to differentiate a past behind them from a future that awaits them. At least this is my reading of Kozyrev's notion of time. The above are summarized in the following table:

Table 1.
Signs of Kozyrev's theory characteristic quantities in our World and in a mirror World

	Our World	Mirror World
δ*r*	+	–
δ*t*	+	+
c_2	+	–

We are assuming that in our World we are in a right-handed coordinate system.

This model gives us an idea about how time differentiates between causes and effects. We may think of the material point representing cause to be situated in a right-handed coordinate system. Kozyrev thought time to have the ability to transform cause into effect by transforming the right-handed system into a left-handed system, i.e. to perform a parity transformation. At this point in order to keep consistent with the above interpretation I slightly differentiate from Kozyrev (see Kozyrev, 1963, p. 4 and Korotaev, 1996, p. 63–65) and I assume that this transformation is done through time's active property c_2 rather than δt which I take as always to represent the world-arrow running for all observers in the same direction. So in Table 1, all we have to do is to write instead of «Our World» the word «Cause» and instead of «Mirror World» the word «Effect». Of course, completely symmetrically we may think of the cause to be situated in a left-handed coordinate system and the effect in a right-handed coordinate system. This would just cause a reverse of the signs for c_2 and δr. The important here is the relative difference of rotations for the two systems which whenever occurs gives us at a description level an objective differentiation between causes and effects (see Table 2). This differentiation of course at an ontological level is produced by the time-field itself.

Table 2.
Signs of Kozyrev's theory characteristic quantities for the cause and the effect

	Cause	Effect
δr	+, –	–, +
δt	+	+
c_2	+, –	–, +

The first sign for δr and c_2 corresponds to a right-handed coordinate system while the second to a left-handed coordinate system. δt in our interpretation retains the same sign for both systems representing the absolute difference between future and past for all observers.

This «rotation argument» of Kozyrev for an objective (absolute) differentiation between causes and effects is somewhat reminiscent of Newton's two globes thought experiment. Newton imagined two globes floating in an otherwise empty space connected by a cord. The claim is that despite the fact that in this empty space «there is nothing external or sensible to which the globes could be compared» we could nevertheless determine the quantity of absolute circular motion (how fast the two objects are revolving around the common center of mass) by measuring the amount of tension in the cord. Newton also claimed that the direction of the rotation (right-handed or left-handed) could be determined by observing the effects (increments and decrements in the tension of the cord) of the forces impressed on alternate faces of the globes. Although Newton used this argument along with his other famous rotating bucket experiment to justify the doctrine of the absolute motion, it is worth to notice how both men (Newton and Kozyrev) used rotational motion in order to establish objectivity.

Since I have used a number of times before the expression «time-energy field», I should give an explanation about this. Although Kozyrev didn't explicitly use these words and referred generally to time as a phenomenon of nature, I think an interpretation along this line is much closer to his ideas. This is supported by yet another property that Kozyrev ascribed to time: the so called *density of time*. This is also a much debated issue, but roughly we can say that time has some kind of energy or more precisely a kind of negentropy which is quantified by its density. Kozyrev imagined that matter generally can emit and absorb time in the form of this energy. When a material body emits time its entropy (disorder) increases whereas when it absorbs time its entropy decreases or in other words its negentropy (order) increases. In order for time to transform a cause into a result, the material body representing the cause emits this time-energy/negentropy and the material body representing the effect absorbs it. All this may seem bizarre to someone unfamiliar with Kozyrev's work but Kozyrev actually supported these results with a series of experiments (for an extensive review of Kozyrev's experiments revealing the active properties of time see Levich, 1996b). We should mention here that it's not just time acting on matter but it's more of a mutual interaction. Kozyrev thought of time as «a mighty flow embracing all the material processes in the universe, and all the processes taking place in these systems are sources feeding that flow» (Kozyrev, 1963, p. 4). So why not think of time as an energy field, a kind of electromagnetic field for example? They both have velocities, energy, density and they both interact with matter. It is a thought and one in my opinion that may lead to a more precise and formal development of Kozyrev's theory.

As every field, time has to exercise some forces too. In fact it is a central postulate of Kozyrev's causal mechanics than in a cause-effect link forces do arise, additional to those predicted by Newtonian mechanics. These forces were calculated through experiments (for a tentative theoretical derivation of these forces see Korotaev (1996), and Shikhobalov (1996b). One may wonder way these forces were not predicted by classical mechanics. Usually the argument goes that the magnitude of these forces is much smaller than the Newtonian forces and so they were neglected. In my point of view these forces are on a different ontological level than the classical ones. They are the forces that transform a cause into an effect in an abstract cause-effect link and shouldn't be thought of as ordinary forces. Here we shall remember Bohm who managed to develop a theory that statistically produced exactly the same results with standard quantum theory. The difference is that in Bohm's theory next to classical potential, a new potential arises, unsuspected thus far by standard QM, the so called «quantum potential». This potential manages to give a completely causal explanation for all observed quantum phenomena, contrary to the orthodox interpretation (see Holland, 1993). Why not draw an analogy between standard QM and Bohm's theory on the one hand and classical mechanics and Kozyrev's causal mechanics on the other hand? It seems to me that Kozyrev's causal forces play a similar role with respect to Newtonian mechanics as played by the Bohm's quantum potential with respect to QM. They both are additional forces needed to give a complete causal account of the theory.

7. CONCLUSION

If we had to give a name to Kozyrev's theory of time from a philosophical perspective that would certainly be *active realism*. Realism on the one hand because Kozyrev certainly believed that time was a kind of entity. The majority of his followers went further in this line of thought considering it for example as «a specific kind of substance coexisting with space, matter and physical field» (Shikhobalov, 1996c, p. 174–175). The substantial notion of time exists of course in the interpretations of the other physical theories we examined except maybe for QM where (see Section 5) there is a problem even defining time. What differentiates Kozyrev's realism from the others is certainly the adjective «active». Time for Kozyrev has certain active properties which permits it to interact with material bodies and processes. Someone would argue that the same more or less is valid for GTR (see Section 4). But there are two important differences. First, whereas in GTR time is considered as an intrinsic part of spacetime, in Kozyrev's theory there is a clear cut between space on the one hand considered as a passive arena where upon material processes take place and time on the other hand considered as an active agent. Secondly, it should not be taken that in GTR mass *causes* spacetime to curve and spacetime *causes* mass to move on a certain geodesic. Rather, as Dainton (2001, p. 294) notices, what we have here is a law-like connection between the intrinsic geometry of spacetime and the distribution of mass-energy through spacetime: certain distributions of mass- energy can only co-exist with certain spacetime curvatures. It's not a matter of one causing the other. On the other hand Kozyrev's theory clearly states that time *causes* things to happen.

As the structure of time is concerned, our proposal was to regard time as certain kind of energy field. My personal conviction is that in this way Kozyrev's theory may be based on more secure conceptual and mathematical basis for its further development. Here is another issue I want to touch before closing this paper. Sadly, it is the modern trend in theoretical physics to regard mathematical elegance more important than experimental evidence. The origins of this thought go back even to Einstein's formulation of GTR but in our days this has reached an enormous proportion. I am referring of course to string theory, where abstract mathematics are accumulated upon more abstract ones with not so ever a piece of experimental evidence to support them. This is sad as I said, because other theories with more physical intuition and experimental backup are ignored by the majority of the physicists. Kozyrev's theory is one of them. Here we have a theory of unique physical intuition and perception and experiments which seem to corroborate its results. What lacks of course is a more precise mathematical formulation.

But that is a secondary thing. History of science proved that whenever we have a solid physical basis, mathematics will eventually find a way to express it.

BIBLIOGRAPHY

Aspect, A., Dalibard, J., and Roger, G. (1981). Experimental Tests of Realistic Local Theories via Bell's Theorem. *Phys. Rev. Letters,* 47:460–467.

Bell, J. S. (1966). On the Problem of Hidden Variables in Quantum Mechanics. *Reviews of Modern Physics,* 38(3): 447–452.

Collingwood, R. G. ([1938] 1991). On the So-called Idea of Causation. *Proceedings of the Aristotelian Society,* 38. Reprint in: A. B. Schoedinger (ed.). *Introduction to Metaphysics: The Fundamental Questions*. 145–162. Buffalo, New York: Prometheus Books.

Dainton, B. (2001). *Time and Space*. Acumen Publishing.

Earman, J. (1989). World enough and space-time. *Absolute versus relational theories of space and time*. Massachusetts Institute of Technology.

Earman, J. and Norton, J. (1987). What price space-time substantivalism? The hole story. *British Journal for the Philosophy of Science,* 38(5): 15–25.

Hilgevoord, J. (2002). Time in quantum mechanics. *American Journal of Physics,* 70: 301–306.

Hilgevoord, J. (2005). Time in quantum mechanics: a story of confusion. *Studies in History and Philosophy of Modern Physics,* 36:29–60.

Holland, P. R. (1993). *The Quantum Theory of Motion: An Account of the de Broglie-Bohm Causal Interpretation of Quantum Mechanics*. Cambridge University Press.

Korotaev, S. M. (1996). *The Logic of Causal Mechanics: Observations, Theory, Experiments*. In Levich (1996, p. 60–74).

Kozyrev, N. A. (1963). Causal mechanics and the possibility of experimental study of the properties of time. *Istoria I Metodologia Estestvennyh Nauk (History and Methodology of Natural Science),* 2: 95-113, Moscow (in Russian). See also Kozyrev, 1991, p. 288–312. Translated in English at

http://www.univer.omsk.su/omsk/Sci/Kozyrev/vsp1.htm.

Kozyrev, N. A. (1991). *Selected works*. Leningrad (in Russian).

Levich, A. P. (ed.) (1996). *On the Way to Understanding the Time Phenomenon. The Construction of Time in Natural Science. P. 2. The «Active» Properties of Time According to N. A. Kozyrev*. World Scientific.

Levich, A. P. (1996b). *A substantial interpretation of N.A. Kozyrev's conception of time*. In Levich (1996, p. 1–42).

Maudlin, T. (2002). *Quantum Non-Locality and Relativity. Second edition*. Blackwell Publishing.

Merell, F. (1991). *Unthinking Thinking. Jorge Luis Borges, Mathematics, and the New Physics*. Purdue University Press.

Muga, J. G., SalaMayato, R., & Egusquiza, I. L. (Eds.). (2002). *Time in quantum mechanics*. Berlin: Springer.

Newton, I. ([1687] 1999). *The Principia. Mathematical Principles of Natural Philosophy. A new translation by I. Bernard Cohen and Anne Whitman assisted by Julia Budenz. Preceded by A Guide to Newton's Principia by I. Bernard Cohen.* University of California Press, Berkeley and Los Angeles, California.

Pauli, W. (1933). *Die Allgemeine Prinzipien der Wellenmechanik.* In Handbuch der Physik, 2. Auflage, Band 24., 1. Teil (p. 83-272). Berlin: Springer.

Shikhobalov, L. S. (1996a). *The Fundamentals of N.A. Kozyrev's Causal Mechanics.* In Levich (1996, p. 43–59).

Shikhobalov, L. S. (1996b). *Quantum Mechanical Uncertainty Relations as a Consequence of the Postulates of N.A. Kozyrev's Causal Mechanics. Forces in Causal Mechanics.* In Levich (1996, p. 109–134).

Shikhobalov, L. S. (1996c). *What can be obtained from the Substantial Conception of Time?* In Levich (1996, p. 174–221).

Thorne, K. (1994). *Black Holes and Time Warps. Einstein's Outrageous Legacy.* London, Picador.