7 LIR AND PHYSICAL SCIENCE: TIME, SPACE AND COSMOLOGY

Abstract The question of the nature of time and space, which determines how one looks at both phenomena and theories of reality, will be explored in this chapter. The LIR view of time and space is compared with current views in general relativity, and the problems of 'subjective' and 'objective' time and of an independent 'background' space-time are discussed. The mode of description of space-time and of the relation of simultaneity and succession in the LIR framework is quite novel, and is applied to issues in both science and philosophy, e.g., to the metaphysics of being and becoming. Quantum mechanics, including the operation of the widely discussed concept of Bohr complementarity, are interpreted in LIR terms. Like relational quantum mechanics, the scientific structural realism of LIR places the emphasis on relations rather than states, while maintaining the role of both. Recent developments aimed at the unification of quantum theory and gravity within general relativity tend to confirm the role of relations as in the LIR framework. The principle of self-duality in these theories may be reflected in the LIR principle of dynamic opposition. A new cosmological theory, the cyclic model of the universe, is examined from the LIR standpoint.

7.1 TIME AND SPACE: PRELIMINARY REMARKS

Classical notions of time and space and of simultaneity and succession still underlie reasoning in almost all of fields of thought and everyday human behavior. To begin to put the LIR theory in perspective, I first will summarize a view of time and space that might be held by a reasonably well-read person[1]:

> (a) Space and time are not independent, but are related by the laws of general and special relativity, such that one should refer to the world as a four-dimensional continuum of three spatial dimensions and one temporal dimension.

[1] I realize that this is a caricature.

(b) Time and energy are also related, in the sense that times closer to the Big Bang correspond to higher energies.

(c) At the quantum level, there are additional dimensions, but they are hidden at the macroscopic level; correlations between states of quantum particles over arbitrary distances are possible (non-separability); and quantum entanglement between states of particles provides a novel basis for information storage and encrypted exchange.

The differences between quantum and macroscopic properties do not seem to have consequences at the phenomenological level. When I am on a trip 3,000 km from my wife, we are not connected in any physical sense, with the exception of the (negligible) gravitational force between us. The clock time to which we refer is the same; we are not traveling at relativistic speeds.

Problems remain, however, since the indicated unification of the notions of space and time in a four-dimensional physical structure is epistemically contradictory to their diversity in phenomenological experience. In addition, even within human experience, there is the possibility, given more than one individual consciousness, of two estimates of 'the' time. I will address in what follows a few of the multitude of issues that are involved in both. For example, the phenomenological problem is one origin of anti-realist views that time, among other things, is what I imagine it to be. The question then becomes, if the solipsist position (only I am real) is rejected, what can account for the consensus between most people on the common measures of time and space? Proving clearly that solipsism is false, in that it violates some fundamental physical principle, has also been difficult.

Another way of stating the problem of time is that given its very real appearance and its probably different but non-perceivable reality that (one assumes) is present in the quantum phenomena that constitute us, and the universe we inhabit, what is the relation between them? Further, is there some assumption we have made in the model presented by general relativity (GR) whose origin is in classical logic that falsifies the debate? I will assume for purposes of discussion that the PDO is accepted and that the axioms of LIR are applicable at all levels of reality, including that of the universe itself.

I will organize my analysis as follows: Section 7.2 will present the LIR conceptions of time, space and space-time derived from the fundamental postulate and axioms of LIR plus its minimum definition of existence as the existence of two 'things' and an oppositional relation between them. Section 7.3 is a review of some concepts of time in philosophy that could now be reinterpreted. Section 7.4 will look at their implications for the philosophy of being and becoming. Section 7.5 introduces the essential correspondences between LIR and quantum mechanics, especially relational quantum mechanics and complementarity. Section 7.6 revisits the entire foundation of the logic of/in reality. It establishes the correspondence of its principles with current realistic formulations of general relativity, which includes a metaphysics of relations that also is an integral part of LIR

theory. Finally, I propose that a recent model of the (currently) expanding universe also can be interpreted in LIR terms. This strategy, I hope, will convince the reader that the principle of dynamic opposition and the axioms of LIR are concepts relevant to the understanding of dynamic phenomena at all levels of reality, including that of the universe itself.

7.2 THE LIR THEORY OF SPACE-TIME

7.2.1 The LIR Categories of Time

I have proposed a category of Process to describe aspects of change or becoming, applicable to real events instantiating the category of Energy (or its quantum field equivalent). We have also seen that the entities of these categories fit the axioms of Conditional Contradiction and Asymptoticity, which require not only reciprocal actualization and potentialization, but that no actualization or potentialization can be complete and absolute.

In LIR, time, space and space-time, as these terms are commonly understood are *not* categories themselves. Rather, they are concepts of dynamisms (Chapter 3) that fit the category of Dynamic Opposition. This leads me to a first theorem of time:

Theorem 7.1: The actualization or potentialization of a logical event is not a function of time, A_t or P_t, but time that is a function of the dynamics of actualization and potentialization, t_A or t_P.

If an actualization of an element or its opposite is rigorous and absolute, there is no more time; the logical element is fixed and immutable. Process as such is impossible. If the consequent potentialization is, accordingly, infinite, the element disappears along with the temporality. The notion of time enters into the concepts of wear, change and transformation, all of which require modification of identity. Complete actualization or potentialization would be equivalent to an end of time, in the heat death of the universe, for example, the absolute homogenization of energy at the lowest level. Time is only possible due to the existence of contradictory dualities whose energetic antagonism is both the source and necessary condition of partial, non-infinite actualizations and potentializations. Time is thus, like the dynamisms that generate it, neither finite nor infinite but transfinite. Again, reversing Kant, time is not a condition of phenomena, but conditioned by phenomena, due to their logical dynamic structure. The first ‘object’ to instantiate both a time and a space would be, of course, the singularity of the Big Bang, or its

latest non-absolute replacement.[2] To repeat, time, like space, as will be discussed, results from the development of a process that actualizes itself, the necessary consequence of the dynamic structure of an energetic world.

This implies that

Theorem 7.2: Objects and events do not exist or take place in time, but are the sources of, or 'unroll' (*déroulent*) their own time.

Classical logic is non-temporal, since its rigorous non-contradiction, pure identity and relations and implications are totally fixed, incompatible with time and change. Together with much else, time is relegated to the domain of the psychological and irrational. Temporal logics are modal logics that introduce operators for discussing *propositions* whose truth is different in an apparent, past, present and future, but these logics do not provide a model for the dynamics of change as such. Smooth Infinitesimal Analysis, which is based on standard logic, captures only temporal aspects of phenomena that are amenable to description by differential equations, but neither the realities of phenomenological time, nor physical realities that are discontinuous or both continuous and discontinuous.

Varela's theory of biological and subjective time, that of Varela, for example, that links time with affect, tend tends to support the LIR view. Standard views of the experience and perception of time (Le Poidevin 2000), blocked in a classical logical framework, do not. As an alternative to the classical philosophical notion of time based on a classic logic of identity and homogeneity, time in the empirical philosophy of Bergson is a heterogeneous duration, psychological, biological, vital, etc. However, it was defined as being outside logic, involving another classical *distinguo* that was simply opposite to that of Kant – what is heterogeneous in Bergson is logical; what is homogeneous is not.

According to LIR,[3] there are three kinds of time: a positive time corresponding to the identifying actualizations of positive ortho-deduction, physico-chemical causality; a negative time inverse to the former of differentiating actualizations, associated with the processes of living matter. The two involve both continuities and discontinuities, like any dialectic process, and their dialectic results in the emergence of a third time, t_T, at the mid-point, corresponding to a minimum of non-contradiction and a maximum of tendency to contradiction, as we have seen elsewhere. This is the time of quantum and neuropsychical entities, which could provide a logical basis for the phenomenological 'nowness' of Varela (1999). In any event, it would be fair to say that the LIR scheme provides a more

[2] See below, Section 7.6.4, on a cyclic model of the universe.

[3] See Lupasco (1987).

thorough description of the relation between 'passivity and activity' and 'invariance and change' than that suggested by the term 'mixture' (see below, Section 7.4.2).[4]

The work of Carlo Rovelli on quantum gravity includes a discussion of the way in which a variable 't' for time can be eliminated from the equations of basic physics. Not only is neither time nor space absolute, but "time does not exist". Equations describe rather the way in which two effectively observable quantities, a beating pulse and an oscillating pendulum, evolve with respect to one another (Rovelli 2006).

One asks not how many beats or oscillations per second, but how many beats per oscillation. There is no reason, in my view, not to extend this concept to other pairs of entities that are in direct interaction.

7.2.2 The LIR Categories of Space

The logic presented here, in which all is process and energy, dynamically contradictorial, is a logic *par excellence* of the *a posteriori*. Therefore, if space is a logical phenomenon, it is *a posteriori*, like time, not a Kantian condition of phenomenal actualizations but conditioned by them. Simultaneity requires space; if events do and do not succeed one another, a required notion of space can develop. The moment two elements exist at once, simultaneously, they imply, simply because they don't coalesce, a space, a location with a distance between them.

By the fundamental postulates of the logic of energetic phenomena, the generation of a transfinite series of dualities of dualities (systems of systems) necessarily generates the logical space for them, which Lupasco called configurations or logical forms. Lupasco identified this space with the configuration space of quantum physics.

The link between space and time is achieved as follows (Lupasco 1987):

> In every actualization, and precisely because there exists an antagonistic actualization relative to a contradictory potentialization and never the possibility of an absolute actualization, a contradictional conjunction (of some sort) essentially and irreducibly accompanies the development of the process of actualization and potentialization. In other words, there is always a simultaneity of an element or event that is more or less actualized and of an element or event more or less potentialized.

This contradictional conjunction is present during the unfolding of any actualization in such a way that one can say that the logical temporality that is generated by energy is always tied to a logical spatiality that is generated similarly. The space of the expanding universe is the space of a dynamism that actualizes or potentializes itself. This concept is thus based on the structure of energy itself and

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[4] Rovelli suggests that fundamental science is in a state of confusion and that existing ideas may not help, "or maybe something is missing and we need a new idea". The PDO is my candidate for the "something that is missing" in science, philosophy and logic.

its logical aspects. There are both spaces and times, which are *proper to* individual phenomena, functions of their actualization.

Thus

Theorem 7.3: Objects and events do not exist or take place in space, but are the sources of, or 'unroll' (*déroulent*) their own space.

Objects are not in space, but space is in objects; objects are not localized, but localize, create localizations. It is in this admittedly informal way that such a space has the same characteristics as a configuration space, that is, it is a function of the number of its elements and of their degrees of freedom; it is what links the elements, their relations, that permits their co-existence in a system and their simultaneity. There is no spatial location outside of what is inside it. Logical space and logical time constitute a space-time proper to each system, a configuration space-time. Time cannot be separated from space, and only space-time exists.

I thus construct three (kinds of) space in an analogous manner to that of the three times: a positive space of the physical world and its matter, of homogenizing causality, of particles following Bose-Einstein statistics and that of the set M of the Axiom of Choice of Zermelo-Frankel set theory (cf. Appendix 2), a space that could be called photonic space; a negative or heterogenizing space of biological configurations, particles following Fermi-Dirac statistics, the sets N of choice, or electronic space; the third is the space of interactive quantum phenomena and of esthetic and psychological phenomena as well as of the sub-sets P of the Axiom of Choice.

Let us now look at the relation between simultaneity and succession.

7.2.3 Simultaneity and Succession

Simultaneity as characterized above is a contradictional *conjunction* that requires the presence of elements that are both identical and diverse; otherwise, the simultaneity would tend to disappear. Simultaneity is spatializing in that it defines or is the locus of the 'three spaces' referred to above and is, accordingly, an energetic operation, not a static given. An energetic simultaneity is thus a 'simultaneization'. It *implies* a passage from a degree of potentialization to a degree of actualization, of a certain quantity of potential energy to a certain quantity of actualized energy, therefore movement, succession and time: "No space without passage from succession to simultaneity and thus without time, and no time without passage from simultaneity to succession, no time without space." One consequence is that simultaneity in LIR is similar to that in current relativity theory. In

LIR, simultaneity[5] can not be considered absolute within one frame of reference, although not for exactly the same reasons.

Thus, succession is considered as a contradictional *disjunction* or *exclusion*, opposed to the simultaneity or conjunction. It also involves identity and diversity of elements at the same time, but succession involves an actualization of a series of identities and potentialization of a series of diversities, something like a choice between contradictory elements or events. Succession in time is a dialectical series of metaphysical 'choices' by a system. Succession is also, in this picture, the passage from a certain potential state to an actual state, and inversely. There could be no succession possible, in energetic phenomena, if there were no potential of succession, of dynamic 'successionizations' and an actualization of this potential. There is actualization of a succession – which is essentially actualization itself – because there is a potentialization of the contradictory succession. Every succession implies this dialectic.

The conclusion is the following: logical space, in the sense of simultaneity or conjunction is dynamically opposed (in a contradictional relation) to logical time as succession or disjunction. The simultaneity of elements in space is based on their succession of time, and *vice versa*. Neither of the contradictional relations being processes ever going to absolute completion, each will always have an irreducible residue of the other; there will always be some space in time, some time in space. This picture is sufficiently novel to warrant a further formulation of the basic points.

For succession to exist, temporality, there must also be simultaneity, spatiality, in which and by means of which succession can operate and develop. Inversely, for there to be space and contradictional conjunction, that which what constitutes disjunction and entails succession and temporality and coexists with space must be potentialized. Since these processes never go to completion, there is always some space in time, some time in space. Spaces and times develop dialectically, following the scheme of ortho-deductions, moving toward, but not reaching, the ideal non-contradictory limits of identity or diversity, or, alternatively, toward a limit of maximum contradiction.

The dialectic of the three energetic times and three energetic spaces defined in Sections 7.2.1 and 7.2.2 and their interaction by contradiction and antagonism constitute space-times or time-spaces. To the spatialization or homogenizing simultaneization of positive space is linked a temporalization or heterogenizing successionization, contradictory and antagonist, a negative time, potentialized by the actualization of that positive space, such that it tends to disappear asymptotically.

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[5] The relativization of the neo-classical concept of simultaneity (or of a plane of simultaneity) to a frame of reference results in paradoxes in assigning times, or rather, temporal sequences, positive, negative or zero for different observers, a concept whose metaphysical significance, is by no means understood. In the context of relativity theory, there is no *a priori* definition of the simultaneity of two distant events, and it becomes subject to an arbitrary or conventional choice, called a convention of simultaneity and synchronization (Petit and Wolf 2005). The sense of simultaneity (and succession) in LIR is in my opinion metaphysically richer.

It is this idealized negation of diversity that gives rise to the intuitive notion of an infinite homogeneous time that contains nothing in itself and embraces everything.

When both simultaneity and succession, that is, what define the structure of time and space, are both semi-actualized and semi-potentialized, one has (Lupasco 1986b) a semi-actualized negative time and a semi-actualized positive space together with a semi-potentialized positive time and a semi-potentialized negative space. This can be defined as the microphysical and mental space-time (T-state). The complicated interactions involved result in the impression, subjective and objective at the same time, that when one observes or observes oneself, there is and is not a psychological time and there is and is not a psychological space in which a person exists and thinks.

The consequence of this picture is that the standard view of synchronicity and diachronicity as well-defined, separate properties does not hold. Subsequent references to processes being synchronic or diachronic (as in the following section), should be understood accordingly.

Perhaps the most important conclusion from the LIR view of space-time is that it is not primitive; in other words, there is no background space-time manifold which is required for the description of entities as there is in theories of quantum physics, strings and quantum gravity. What I have not yet given an LIR interpretation for so far are fundamental questions that remain as to the presence, persistence and spatio-temporal location of the objects, including relations and processes, whose dynamics I have characterized. To do this, I will look in Section 7.6 on Cosmology at current developments in relativity theory, in order to take into account the role of the gravitational field. I agree with the often made point that metaphysical issues must not be conflated with a literal interpretation of physical theory, but I feel the two cannot be maintained as totally independent, and LIR offers some metaphysical options that may be useful.

7.2.3.1 Synchronic and Diachronic Logic

In the period 1950–1970, Suszko developed a concept of a distinction between synchronic and diachronic logic that should be positioned relative to the LIR theory of time. A synchronic logic consists of a language, axioms, a consequence operation and interpretations (models) as usual (cf. Chapter 1). A diachronic logic purports to be a formal representation of evolutionary and revolutionary changes in scientific theories and of human knowledge in general. It thus would appear to occupy much of the conceptual space of LIR.[6]

As it turns out, however, Suszko's approach to change was strictly formal. He constructed a framework for abstract notions of the epistemological properties of the human subject within which diachronic logic gives only very general information about the development of knowledge. This logic *could not*

[6] I am grateful to Professor Jean-Yves Béziau for bringing the work of the Polish logician Roman Suszko to my attention.

consider non-formal or what he called pragmatic (and I call dynamic) aspects of knowledge. The 'diachronicity' in this logic is limited to a difference in the way a "subject with semantic notions concerning itself can talk about its earlier and future stages". The Suszko program, accordingly, remains for me within the domain of binary logic.

7.3 SOME ALTERNATIVE VIEWS OF TIME

This section will give the opportunity of comparing the LIR theory of time and space with a number of few familiar ideas, all of which refer to problems associated with phenomenological time. This will enable the fundamental difference in my point of view to become further apparent. The consequence is that application of the PDO in this field may be both desirable and feasible.

7.3.1 Time in Philosophy

It is impossible to even summarize here what has been written since antiquity on the subject of time as an aporia. In any event, the few prior intuitions of a more complex structure of time can be subsumed under the concept of 'both at once', and the medieval *coincidentia oppositorum*.

A standard philosophical view of time is that it is 'paradoxical' (Levinas 1998). What more, however, do we now know than before? In my view, we know little more than the commonsense concept of a flow. This is in a sense going backwards from Heraclitus, since the latter said all *things* flow, not time.

Also pertinent are the ideas of Derrida (1993), whose concepts of deconstruction have influenced much of current philosophy.[7] Derrida begins with the Aristotelian definition of time as an exoteric aporia, both entity and non-entity. He criticizes the philosophical tradition from Kant to Hegel, suggesting with Heidegger that the Hegelian dialectic is a 're-edition' of the Aristotelian exoteric aporia, and remains a 'vulgar concept of time'. Derrida then asks if this exoteric aporia is irreducible and calls for an "*experience* other than that consisting in opposing, from both sides of an indivisible line, another concept, a non-vulgar concept, to the so-called vulgar concept." Finally, Derrida asks (all these points are formulated as questions) if (such) an experience can surpass an aporia, or else, "putting the experience of the aporia to a test, "And is it an issue here of an *either/or*? Can one speak – and if so in what sense – of an *experience of the aporia?* An experience *of the aporia as such?* Or vice versa: is an experience possible that would not be an

[7] I have followed here the English translation of his *Apories*.

experience of the aporia?" This is a kind of 'philosophy of experience' that can be related to the discussion of LIR and experience in Section 6.9.[8]

Although Derrida makes his analysis here primarily with reference to concepts of time and death, it is clear that he intends it to apply to other phenomena – "the interminable list of the so-called quasi-concepts that are so many aporetic sites or dislocations; the double bind, the 'non-dialectizable contradiction', etc." As with regard to other issues in this book, my objective is not to arrive at some final conclusion about time in philosophy, but simply to point to some alternative ways of talking about time that make sense from a metaphysical, logical standpoint.

7.3.2 Time in Phenomenology

One original contribution to the phenomenology and philosophy of *time* is that of Varela (1999) who says, "The familiar account of time inherited from our modern Western cultural background is inadequate". However, he also states that: "The experience of temporality addresses head-on the fundamental fact that we exist within a transparent web of time." Husserl's view of subjective time was that of a paradoxical appearance of 'double intentionality', a mixture of passivity and activity, of invariance and change. Temporality is constituted through complementarity between spatial and dynamical ingredients, affect, and trajectories in a phase space landscape.[9] A dynamical 'mutual bootstrap' principle applies such that the trajectories provide the "conditions for an embodied coupling, since through their coupling they shape their dynamical landscape. Metaphorically, the walker and the path are intrinsically linked." Varela refers to his neuro-phenomenological hypothesis that states:

> Phenomenological accounts of the structure of experience and their counterparts in cognitive science relate to each other through reciprocal constraints.

Given two accounts – a process of external emergence with well-defined neurobiological attributes and a phenomenological description that stays close to our lived experience – Varela asks for a 'circulation' between them, that is, their mutual or reciprocal constraints, "*including both the potential bridges and contradictions between them*" (emphasis mine).

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[8] My approach, here as elsewhere, provides a dynamic link between the terms of an aporia, and thus both corrects and amplifies the line of historical argument on time that Derrida developed. I suggest that one should see the Derridean experience as an emergent included middle between the either/or terms of the aporia.

[9] I notice that while the concept of time is given substantial development, the standard concept of space (including phase space) seems perfectly adequate to the author and does not receive additional comment.

A number of questions can be asked here, in relation to the development that follows:

- Does a web of time exist, or is this a metaphor?
- How can 'passivity and activity' be mixed?
- Is 'embodied coupling' real or also metaphorical?
- From where might 'contradictions' come and what is their significance?

From the LIR standpoint, such views fail by postulating an independent subjective temporal flow within which entities and their relations are located. According to Grush,[10] Husserl had the better intuition that it is the relations themselves that constitute the flow of subjective time. The LIR system, that takes words like coupling, contradiction and constraint seriously and asks that their content be defined, is no more (and no less) in my view than well-intentioned criticism.

A concept of time being deployed by objects or systems might thus be generally employed as a rule rather than an exception. A significant example is that of biological time, such as circadian rhythms, as a function of biological processes. The primary area of application of what I have described in Section 7.2.2 as the *three* contradictorially-related forms of space-time is that of subjective time as a function of human cognition. However, further development of this application must await a detailed discussion of the LIR view of the origin of consciousness and knowledge which is outside the scope of this book.

7.4 BEING AND BECOMING IN MODERN PHYSICS

A review article with the title "Being and Becoming in Modern Physics" (Savitt 2002) confirms the point in Chapter 3: it contains no definition of what it is to be. The problem is addressed essentially as that of a definition of time: "Does time flow or lapse or pass? Are the future or the past as real as the present?" Nevertheless, the controversy that already existed between Heraclitus and Parmenides and their respective followers is a good place to start the discussion. The three 'rival' metaphysical views of time are

- Presentism = "Nowism" > Only the present is real (Heraclitus).
- Possibilism = "The Tree Model" > Past and present are real.

[10] Grush (2006). The discussion here of content/vehicle confusion in theories and the need for a 'middle-level' theoretical framework that can bridge, without reliance on metaphor, the temporal profiles of the content carried by a representation with the vehicle – the material substrate of the representation. LIR is a candidate for such a theory.

- Eternalism = "The Block Universe" > Past, present and future are equally real (Parmenides).

Of the above, the possibilist view is the easiest to accept intuitively, and it accounts most easily for the asymmetries between past and future.

7.4.1 Tensers Versus Detensers

An on-going debate in the standard philosophy of time revolves around whether or not time is tensed or tenseless. For the tenser, events only truly exist in the present, and they posses properties of pastness, presentness and futureness. This is the classical 'presentism' view. The tenseless theorist denies that events possess those transient properties and instead stand in the unchanging relations of earlier than, simultaneous with, and later than, one another ('eternalism').

Q. Smith (1986) defends the tensed theory by showing that the early 20th century criticism of it by McTaggart, to the effect that the idea that presentness, pastness and futurity are attributes of events entails a vicious infinite regress and a consequent contradiction, fails to hold. McTaggart argued that time is unreal because the concept is self-contradictory: the idea that presentness, pastness and futurity are attributes of events entails a vicious infinite regress and a consequent contradiction. Smith adopts a number of strategies, which will not be reproduced here, to show that McTaggart's assumptions (e.g. of hierarchies of levels of predications and inherences[11]) are not valid. Further, that "the infinite regress of genuine and necessary temporal predications is a *regress* of *analysandum* and *analysans*[12] (benign regress), not of contradictions and attempted resolutions, and consequently lacks the viciousness that McTaggart attributed to it.

Although suggested by the "facts of immediate experience and science", it is not logically necessary, as assumed by McTaggart, that events occupy moments. However, without a logic of dynamic opposition, this is an abstract statement that simply denies the commonsense intuition. More importantly, the regress, albeit benign, is still an infinite one. The ontological character of pastness, presentness and futurity, involving an infinite number of inherences is maintained. Smith believes that detenser theories of time are mistaken, that the indicated properties are "essential and mind-independent elements of time", but, interestingly, if these theories were correct, there *would of course be no regressive position*, and thus there is no reason why (infinite) benign regresses cannot exist in reality. "The concept of such a regress is not self-contradictory and hence is able to have real instances." Elsewhere, he claims to have shown that the notion of an actual infinity is not self-contradictory and is applicable to reality.

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[11] These inherences can be understood as something like potentialities in LIR.

[12] An *analysans* is a sentence that makes explicit something implicit in the *analysandum*.

McKinney (2003) cuts through the debate between tensers and detensers by showing that they have no shared semantic or metaphysical starting point (e.g., *re* existence), and the resulting confusion traps both sides in question begging arguments. The tenseless view could be supported if it were clear that two different languages are being used, and that of the tensers does not represent reality, in that logical connections among sentences in ordinary language do not represent ontological connections between facts in the world. However, the tenseless view has failed until recently to provide a satisfactory account of becoming.

In the conception of space-time in general relativity discussed in Section 7.6, eternalism is related to *perdurantism* (Lusanna and Pauri 2006), in which objects are taken as persisting and being temporally extended and made of different temporal parts at different times. Presentism is more like *endurantism*, in which objects (including people), persist by being wholly present at each moment of their history. As might have been predicted by an application of LIR principles, it would appear that the term 'wholly' and accordingly a simple endurantist view cannot be defended, and aspects of an extension of the object in time, including maintenance of the tenseless, observer-dependent relations of "earlier than", "simultaneous with" and "later than" are required for a complete picture. The attributes of "past", "present" and "future" are tensed in the sense that their meaning is dependent on a temporal perspective of an observer.

The question remains as to whether the metaphysics of LIR provides any insight into the key problem of the arrow of time, that is, whether fundamental *physics*, and not an obsolescent concept of abstract time, is tensed or tenseless. My answer would be no more than a restatement of the conditions of the existence of the actual world. The (relatively) modest of objective of my logical approach is to suggest some insights into unstudied aspects of change or process, categorial concepts that require time-asymmetry. It is certainly not known with certainty at this time whether the dynamical structures in the universe reflect a fundamentally tensed reality or whether eternalism – the 'block' universe – is the in part a correct description. The answer may depend on further advances in cosmology, along the lines of the cyclic model proposed by Steinhardt, discussed below in Section 7.7.1. Even for events playing themselves out at ordinary macroscopic levels, the elimination of absolute spontaneity and succession, and the relativization of times to *both* tendencies toward decreasing and increasing entropy provides both identity and diversity as described above provide an alternate way of thinking about phenomena and their interrelationships.

7.4.2 Being and Becoming Revisited

The deepest problem in the metaphysics of time, or in metaphysics *tout court*, has thus been how to understand *any* passage or becoming and its relation to existence. From my standpoint, the difficulties in the various pictures of becoming and its relation to being arise due to neglect of the dynamic, contradictory, antagonistic aspects of the terms used: simultaneity, passage, space-time,

etc. Passage as usually defined without antagonism *is* self-contradictory and absurd, because it excludes an interactive contradictory relation between time and space. Passage is both objective and subjective (in both the broad sense, as the locus of actualization and in the usual sense). Savitt cites Carnap's statement that "all that occurs objectively can be described in science" and then argues that passage (becoming) reflects something perspectival or subjective and *so is implicit in physics or rightly omitted by it* (emphasis mine). From the LIR perspective, it (becoming, the perspectival or subjective) is indeed implicit in physics and should not and does not need, for this reason, to be omitted from it.

Temporal becoming, in a view derived from Broad and Gödel, does not need to resemble motion nor qualitative change; there can be, it is claimed, an *absolute* becoming that is just the successive happening of (simultaneity sets of) events. One is here quite close to the relative becoming of LIR, except that the latter provides a dynamic for the 'happening', and assigns a meaning to 'just', by the oppositional categorial linking of simultaneity and succession, as indicated above.

Having made this proposal, and if eternalism in the detenser sense is not valid, what then is *being* in LIR? I made a start on a discussion of being in Chapter 3, where I said that being and non-being were terms 'of art' that describe in some way the totality of the universe, related to what I have defined as the real in Chapter 1. I would also suggest that being and becoming, *as concepts*, clearly stand in the dialectic relationship to one another defined in Chapter 5: as one thinks of the world as being, the world as becoming is potentialized and *vice versa* in the usual way.

A more standard philosophical discussion of being is that of Heidegger. Heidegger provides some perhaps unexpected (and certainly unintended) support of a dynamic view of contradiction in reality when he describes 'being' as both wholly indeterminate and at the same time highly determinate. "From the standpoint of the usual logic we have here an obvious contradiction: …determinate, wholly indeterminate being. *If we decline to delude ourselves* (emphasis mine), ... *we find ourselves standing in the very middle of this contradiction. And this stand of ours is more real than just about anything else we call real; it is more real than dogs and cats, automobiles and newspapers.*" As in LIR, it is contradictions that are fundamental to reality, being characterized by its contradictorial relation with non-being, as well as with becoming. Jacquette is correct in saying that Heidegger based his conception on human experience, but it is not a criticism to say, as I do, that it is more fundamental than Heidegger thought! Heidegger saw that the constraints on thought imposed by classical or traditional logic ("a court of justice, established for all eternity": Heidegger 1959), of which the principle of non-contradiction was the cornerstone, were unacceptable, and his idea finds confirmation in LIR.[13]

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[13] Aerts differentiates between a process view of reality that includes being and becoming, and a geometrical view, that discusses only being, and shows that there is no contradiction between them. One is dealing, of course, with two views of being – the physical and the metaphysical, but the distinction may be losing force: in the latter, being seems also to mean the normal physical

I will cite a few of Savitt's further statements and quotations, recognizing that they do not all represent his own point of view and my rebuttals:

1. "Motion is one sort of change, change of spatial position with respect to time. The motion of time, then, must be change of time with respect to … What?"
LIR: … with respect to space.

2. "In order for a thing to change it must evidently persist at least from t_1 to t_2, but the events usually supposed in discussions of passage are instantaneous events, which have no duration at all."
LIR: Absolute instantaneity and its problems are excluded axiomatically.

3. "Future facts that do depend on human choice or quantum measurement, should they be facts now, would seem to constrain human choice or quantum measurement in ways that many philosophers find undesirable. It is easy to convince oneself, then, that future facts of these two sorts cannot really be part of existing."
LIR: They can be, if they are looked at as current potentialities. It is not necessary to separate the real (actual) from the potential *via* a metaphysically distinguished present.

4. "If some distinction can be made between categorical and non-categorial existence statements (that is, events exist in the categorical sense, but particular events can be past, present or future), then eternalism is not a straightforward consequence of adopting the space-time treatment of special relativity.
LIR: The dynamic concept of simultaneity and succession is in line with this, and eternalism can be rejected.

The approach of Stein, cited by Savitt, seems realistic. Stein assumes a two-place relation R such that Rxy means that y has already become or is definite with respect to x, and this can be developed into a 'genuine relation of becoming'. Interestingly, Stein wanted to tie his definitions of temporal concepts to intrinsic geometric structure. This opened his relation R to criticisms that Savitt shows are unjustified. The atemporal Minkowski diagram (light cone) represents the evolution of systems along their world lines. Such diagrams do not require 'animation', an artificially attributed 'motion'. In Stein's geometric picture, the transience or passage is in what it depicts. LIR is compatible with these intuitions and could be designated, in this context, as an *adequately relativized possibilism*.

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contents of the universe, without 'time', but the NEO categorization of them as Process and Energy is needed to adequately characterize both being, becoming and their relation (Aerts 1996).

What I mean by adequately relativized possibilism is the following: the thought experiments offered in support of the relativity of simultaneity all seem to involve cosmological, relativistic distances (by analogy with relativistic speeds). They perhaps describe phenomena occurring at some kind of limiting state, in which the contradictorial relationships between time and space, simultaneity and succession might well be altered. Axiom **LIR5** excludes such classical-type limits. The concept of the relativity of simultaneity as "the point of departure for our metaphysical questions rather than the answer to any" cannot be supported. My view of simultaneity and succession does not require frame-of-reference arguments.

Further to this is the question of the relativization of *existence* to a frame, "a difficult notion to understand or accept". Savitt quotes Gödel to the effect that "The concept of existence … cannot be relativized without destroying its meaning completely." And then asks

> Is the concept of existence, then, like the concept of truth, which, when relativized (as true-for-me, true-for-you), comes to something more like belief than truth? Or is it like simultaneity, about which thoughtful persons a century or so ago might have made pronouncements much like Gödel's? This difficult and fundamental question has by no means been resolved.

I suggest answers to both points: 'truth' is more like belief looked at in its dynamic aspects that also apply to existence. Second, simultaneity in LIR has an interpretation that is not *relativized* as in the original or current standard theory but *related* functionally to its conjugate – succession.

"Being and Becoming" is also a section title in a paper by Aerts (1996), who says that:

> Although we know from Einstein's analysis of the concept of relativity that we cannot retain the classical view on reality, as being the collection of all simultaneously happening events, there has not been proposed a real relativistic equivalence for reality in a serious way.

From the LIR point of view, one is dealing here exclusively with becoming, not being. The introduction of time as a fourth geometrical dimension, and the proposal of the space-time continuum as the "real scenery of reality" was incomplete. In this interpretation, there is no change – it is the eternalist picture criticized above. Aerts and others, as we have seen, showed that this result is a consequence of an incorrect view of reality, and that one can accommodate both a four-dimensional space-time continuum and change, combining process and geometric insights.

In an Einsteinian interpretation of reality, the possibility of relativistic time travel enables one's presence 'tomorrow' at an existing location to be, in Aerts' terminology, a 'happening', a determining part of his real, present experience "an actuality and not just a potentiality". The advantage of my approach, as compared to that of Aerts and the standard geometric views, is, as in the previous discussion of simultaneity, that no appeal to travel in a relativistic space-time is required to confirm the current existence of reasonably stable future

entities and events involving oneself by reference to a hypothetical ability of directly observing them.

Aerts elsewhere (1999) describes a 'creation-discovery' view of change: things make their place instead of having a place. Contrary to the 'space-contains-reality' hypothesis, reality is not contained within space. "Space is a momentary crystallization of a theater for reality where the motions and interactions of the macroscopic material and energetic entities take place." Quantum entities 'take place' outside this space within a space that "is not the three-dimensional Euclidean space." The theory describes reality as a kind of pre-geometry, where the geometrical structure of the material universe arises as a consequence of interactions that collapse into the time-space context (Aerts and Aerts 2004).

It is intriguing to consider that this 'space' is what I have described as T-state space-time. The realism of LIR implies this kind of connection between the systems of systems that constitute all human personal realities and provides the account of 'reality' that is independent of them. However, without the aspect of dynamic opposition, one has no basis for the proposed model, which resembles other systems of thought in which geometry is emphasized at the expense of dynamics. In other words, scientific theories that purport to be realist but minimize or ignore dynamic opposition as fundamental must be seen as idealist in the same sense as the binary logic from which they derive.[14] I will return to this issue below in Section 7.6.

Hawley (2006) has asked whether science can guide metaphysics, since she is concerned that traditional metaphysicians are more or less, rather less than more, justified in questioning some of the metaphysical claims made by, or inherent in, current science. The most pertinent example revolves around the nature of time and presentism, which as noted above is the belief that only present objects and events exist. LIR talks directly against naïve presentism by supporting non-absolute concepts of simultaneity and succession as applicable to space-time. The present is not an absolute, but it does not have to be frame-dependent as in special relativity. There is epistemological ignorance of the now-ness of distant events, but the potential event that we will not know about for ten years exists in the present nonetheless in a contradictorial manner, as a potentiality.

My position in this book is that the overwhelming direction of flow of concepts between science and metaphysics should be from the former to the latter. However, by augmenting the doctrine of scientific realism with a, in my view, neglected element of science with a strong metaphysical character, namely, the dynamic opposition of fundamental physical dualities, including their non-actual but real aspects of potentiality, I claim that I have accomplished two things: I have decreased the dependence of structural realism on non-intuitive, mathematical structures, that is, by introducing the more accessible concept of process structures as the basic furniture of our world, and I have given traditional metaphysicians a

[14] It is 'logical' therefore, that in the 'hidden variables' quantum theory of Aerts, the concept of superposition of states in quantum entities is "no longer seen as a general principle which is always satisfied".

basis for principled avoidance of either reductionism or anti-realism as preferred strategies for talking about existence. To the extent that LIR provides a non-circular picture of being and non-being, and being and becoming, and at the same time supports the principled extension of quantum mechanics to macroscopic phenomena, it supports the convergence of metaphysics and physics without reduction of one to the other.

7.5 QUANTUM MECHANICS

The advent of quantum mechanics in the 20th century resulted in a 'revolution' in science and philosophy, and basic ideas of what constitutes objective reality, as opposed to our subjective experience of it, became problematic as a consequence. This revolution is ongoing, and there is yet no agreement on the implications of quantum mechanics for the other major problems of existence – the origin of life and individual, first-person consciousness. In this book, *I have suggested that an equally revolutionary change of perspective is required to see the relation between such concepts as subjectivity and objectivity themselves*. LIR, in my view, facilitates the inclusion of philosophical and metaphysical principles in science and *vice versa*, and should have a place in their mutual development. This idea is echoed in Sklar's suggestion that "Physics and philosophy (including metaphysics) are two highly interdependent ways of seeking to understand the world and our place as knowers of it (Sklar 1992)."

Sklar suggests a different an approach that "looks for the resolution of the problems (inherent in the quantum view of the world) in a modification of our traditional thought concerning some of the most pervasive and general modes we have for describing the world", in my terms, logic. He asks whether a revision of our standard logic itself could help us make sense of quantum phenomena. Instead of logic being immutable and independent of experimental knowledge, perhaps it (logic) is just as much an empirical matter as chemistry and geometry is now taken to be. However, quantum logic *per se* does not resolve all dilemmas about quantum paradoxes, indicating not that quantum mechanics and quantum logic cannot provide a complete description of the world, but that something was and may still be missing from this logic as well.

By this time it is clear that an explanation of the experimentally demonstrable quantum features of the world will (still) require a radical rethinking of our metaphysical picture of it. At the latter level, the one of greatest generality, the definition of some principle that is missing or has been ignored would have major consequences for the future of 'reason' in the broadest possible sense. As indicated in this book, there may exist aspects of physics that are already accessible that could fit this description.

There is a hint of this in the usual description of the possibility (1) of salt dissolving in water that depends on (2) a piece of salt having an actual constitution of ions. If the structure of space depends only on the collection of all possible

spatial relations, what is the underlying reality that grounds this structure in the same way that the structure of salt is grounded? I have outlined a structure of reality in Chapter 5 that offers a possible answer to the second phrase about salt: the process requires the *potential* energy of solution, something that is still a 'substance' in the classical sense, but is not burdened with the necessity of being actual and localized.

Cao (1997) takes another ontological approach to modern physics with regard to the development of field theories. Like Sklar, Cao sees the synergy – 'mutual penetration' – between physics and metaphysics, considering that physics has also provided us with a direct access to metaphysical reality. Cao describes another debate, over the nature of energy, and makes an important suggestion, close to the thesis of this book: "What if energy is taken as substance *with the new feature of being always active, always changing its form while keeping its quantity constant* (emphasis mine)? Then energeticism would seem to be a precursor of James's functionalism and Whitehead's ontology of process." The principles presented in this book show the validity of this intuitive view of the 1st Law of Thermodynamics as well.

Cao's theory is also of interest to me for two other reasons: he retains both the currently less used S-matrix theory (SMT) as well as Quantum Field Theory (QFT) and suggests that their interplay, which has been neglected, may turn out to be useful in furthering understanding. This is an example of an interaction between *theories* where the principles of LIR and NEO can be applied. In addition, in SMT, as in Ontic Structural Realism processes and relations rather than entities are individuals constitute the basic ontology rather than; in QFT, fields or particles are the basic entities. The second reason is his concept that the growth of scientific knowledge is not unilinear but dialectical. Convergence to some form of fixed truth is incompatible with the latter, while a concept of scientific structural realism, compatible with the LIR view, is strengthened (see Chapter 6).

7.5.1 Two Complementary Logics of Complementarity

It has by now been amply documented that the Copenhagen interpretation of Quantum Mechanics (QM) is a reduction of the original profound insights of Bohr as to the real nature of quantum phenomena and their description, a reduction of which Bohr was aware (Faye 2002). Part of the problem was and is due to the absence, in both scientific and non-scientific language, of the necessary terms for dealing with the contradictory aspects of quantum particles (Nicolescu 2002). I claim that if one goes over the requirements that Bohr himself set for a proper theory from the standpoint of the logic of/in reality, one can provide an interpretation that satisfies these requirements.

Bohr's principle of complementarity as a fundamental aspect of quantum objects is one of the major advances in thought of the 20th century. Bohr asked physicists, essentially, to accept A and non-A, wave and particle characteristics of

a quantum particle, and its space-time description (kinematic) and causal (dynamic) descriptions at the same time. More accurately, the *explanandum* was that A or non-A was observed depending on what theoretical or experimental questions were being asked. But what could this mean? In the absence of a firm definition by Bohr, the complementarity principle came to be discussed as something like a simple juxtaposition. Apart from providing no explanation or description of how one aspect insured the continuous existence of the other, this picture does not seem adequate where A and non-A appear to have such a drastically different character in both cases.

Bohr's early work indicates that he viewed complementarity as primarily an epistemological principle:

> The very nature of quantum theory forces us to regard space-time co-ordination and causality, the union of which characterizes classical theories, as complementary but exclusive features of the description, symbolizing the idealization of observation and definition respectively.
>
> The term 'complementarity, which is already coming in to use, may perhaps be more suited also to remind us of the fact that it is the combination of features which are united in the classical mode of description but appear separated in quantum theory that ultimately allows us to consider the latter as a natural generalization of the classical physical theories.

Later, Bohr seems to have moved toward a more ontological interpretation: phenomena or information were mentioned as being complementary, rather than descriptions.

> The phenomenon by which in the atomic domain objects exhibit the properties of both particles and waves that in classical, macroscopic physics are mutually exclusive categories.

If the fundamental nature of dynamic antagonism is accepted, a real contradictorial relation in quantum phenomena is neither physically nor logically unacceptable, and it can have both epistemological and ontological aspects. It is not physically unacceptable because wave and particle properties are not fully instantiated at the same time, until the measurement of one potentializes the other. It is not logically unacceptable for exactly the same reason. Two answers can be given to the objection that this formulation simply restates the result of experiment: (1) if the particle aspects are actualized, the wave aspects must be present as potential, and *vice versa*, otherwise it is difficult to explain how they could reappear; (2) it is not in the LIR view that there is any problem with the observed duality of quantum entities in the first place.

If one assumes, for the sake of argument, a principle of non-contradictory complementarity, one comes up against the limitation to the precision of measurement of the Planck constant, the constitutive 'contradiction' in nature (Lupasco 1987). This means that one or the other aspect can only be partially and never completely actualized, and the other subject to an indeterminacy that can be represented by its potentialization. Contradictory processes, identification and diversification, or attraction and repulsion, go toward the limits in both directions

of actual non-contradictions and a potential non-contradiction (actual contradiction), but they, like contradiction, are only relative, due to the nature of energy. At the macroscopic level, classical physics, infinitesimal differential calculus and mathe-matics based on rigorous non-contradiction and continuity work (very) well. It is clear that the laws governing the macrophysical level of reality approach the laws of classical physics, but only statistically and probabilistically. To this extent, rea-lity always retains or conserves a contradictory foundation.

Some of Bohr's own requirements for an adequate theory, as summarized by Faye, are the following (his numbering):

> 6. The concepts of classical physics are the exact specifications of the common categories of pre-scientific experience (commonsense) notions of position, change of position, cause and effect that are part of everyday language.
> 7. 'Classical concepts', if not classical physics, are a precondition for understanding and communication regarding the results of experiments.
> 11. In a quantum mechanical description, experimental objects and measuring devices are not totally separated, but parts of the measuring device may be treated as parts of the object.
> 14. Quantum phenomena are complementary in the sense that their manifesttations depend on mutually exclusive measurements, but that the information gained exhausts all possible objective knowledge of the object.

Bohr believed that kinematic and dynamic properties, represented by conjugate variables, could be ascribed to quantum objects only in relation to actual experiment, whereas classical physics in his opinion was idealist in assuming that the physical world has such properties independent of their actual observation. One is thus back to an *anti*-realist semantic interpretation of QM in terms of truth conditions of sentences about quantum objects. For this study, what is important in Bohr's later view is that when justified by experimental outcomes, kinetic and dynamic variables have ontological implications for the reality of quantum entities, and the Heisenberg uncertainty relation is not merely an epistemological one of limitations on our knowledge of the system. It is phenomena and information that are complementary, rather than only descriptions (although they may also be complementary as theories, cf. Chapter 5). Bohr believed quantum entities were real, although QM does not give a 'picture' of this reality.[15]

The LIR system is applicable to the above points. For example, as discussed earlier in this book, the concept of conflict or dynamic opposition, now actual and now potential, is also an integral part of human experience and inheritance, and thus classical in the desirable sense of point 7 above.

Béziau states that "there is no principle of complementarity, and complementarity is just a word for some philosophical ideas, for an insight that Bohr was

[15] The LIR dynamic model does not add directly to this picture, but is a way to conceptualize moving from one picture to another.

never able to formulate in a clear way." It is correct to say that the common understanding of complementarity is too vague to be of metaphysical value. Béziau develops a paraconsistent approach that sees the different sets of experiments on quantum phenomena as different viewpoints that can exist without being trivial in a Jakowski-style logic of discussion (Béziau 2001). However, I also feel that Bohr, toward the end of his life, had developed a coherent philosophy to the point where it accepted a concept, which is the fundamental concept of LIR, of the complementarity of opposites[16] in an ontological sense.

Returning to physics, it seems clear that Bohr was seeking a way to justify point 11 above regarding the separability of measurement object and measurement device. This can only be done, in my view, by modifying the concept of parts and whole along the lines of my discussion of scientific structural realism and non-separability.

Bohr was apparently suspicious of the ability of various modifications of classical logic, as it was understood in the mid-20th century, to assist in the definition of quantum physics, although the failure of non-commutativity and non-distributivity of quantum variables, which suggest non-Boolean algebra and logics, were well known. It was only in the 1980s, with the advent of paraconsistent logics, that the first major new approach to the formal explanation of the principle of complementarity became possible.

Da Costa and Krause (2004, 2006) present an interpretation of complementtarity as a general principle of *incompatibility* in the sense that the logical combination of complementary aspects into a single description requires a non-classical logic. Although complementary propositions are acceptable, their conjunction seems not to be valid. 'Mutually exclusive' or 'complementary' refer to incompatible sentences or propositions whose conjunction lead to a contradiction in classical logic. These authors develop a notion of *C*-theories (complementarity theories) whose underlying logic is paraconsistent. They say specifically, however, that their system is not intended to be a condensed account of all Bohr's ideas, in particular, the potential extension of complementarity to other, macroscopic domains. This interpretation does not mean that contradictory propositions are always contradictory, and hence this group of logics is termed paraclassical: the expression, "x is a particle entails that x is not a wave" does not indicate strict contradiction. In *LIR* terms, that x demonstrates particle properties entails that wave properties are potentialized.

In my view, this underlying logic for *C*-theories is very largely adequate for discussing the epistemological requirements of quantum theory. However, the above discussion indicates that Bohr was also in part a realist, and made an

[16] Bohr chose the Taoist yin-yang symbol for his coat of arms when he was awarded, in 1947, the Danish Order of the Elephant as well as the Nobel Prize. The Latin motto reads: "Opposites are Complementary", suggesting that Bohr believed complementarity as metaphysical antagonism to be the most fundamental principle of existence as a whole. The Tao involves, however, not only *Yin* and *Yang* but their conjunction, which one might see as an emergent included middle T-state.

implied ontological commitment to the real existence of the phenomena. (That some-one is both realist and anti-realist is perfectly acceptable in the LIR framework, provided one avoids the requirement of 'both-at-once'.) Perhaps responding in part to this, da Costa and Krause have extended the concept of a *C*-theory by de-fining 'complementarity theories with meaning principles', termed C_{mp} – theories. The purpose of this extension is to accommodate complementarity as a meta-theoretical principle of science, keeping it a kind of meaning principle due to its resemblance to the idea of the existence of contradictions in paraconsistent logic. This might make it unsuitable for acceptance in the polite company of classical logic, but it helps in understanding and accepting incompatible information. In fact, da Costa and Krause show how complementarity can be seen from perspec-tives, as "standing for both a general regulative meaning principle and also as a (strict) law that can be internalized in the language of the theory proper". In other words, the concept of complementary propositions can also be put within a certain object language without making the entire theory trivial. The underlying logic of complementary propositions in C_{mp} – theory is the paraclassical logic mentioned above.

The vision expressed by these theories is congenial to LIR. It suggests an opening to new types of logic, perhaps such as LIR, which offer new perspectives for treating domains of science from different perspectives with new logical apparatuses. Da Costa and Krause, following Englert, suggest that complementtarity may be more general and more fundamental to quantum mechanics than the Heisenberg uncertainty principle. Further, that their logic could be modified to treat even more general kinds of incompatibility, 'physical incompatibility', incurporating physically incompatible postulates, such as human behavior.

The concept of something like complementarity as extendable to physical phenomena is, of course, the core thesis of my logic of/in reality! The major difference is not only that I designate a PDO as my metaphysical and metalogical principle, but that it includes *ab origine* the physical basis for change and emergence that are required a description of reality above the quantum level. In my view, the PDO has been ignored or rejected from a formal logical standpoint based on absolute non-contradiction and limitation to propositions and their mathematical equivalents. The paraconsistent logic and metalogic of complementtarity of da Costa and Krause are thus steps in the right direction, that is, toward a logical description of real phenomena, but in my opinion they do not go far enough.

The application of the PDO and the categories of NEO to each critical feature of the quantum and non-quantum world, at the level of *both* reality and descriptions of reality, resolve some of the paradoxes resulting from standard interpretations. The necessary concepts are the non-separability of individuality and non-individuality; part and whole; subjectivity and objectivity in relation to the experiment-experimenter pair; and of object and meta-levels of theories. LIR grounds the commitment to the reality of quantum entities that is necessary for the ontological view of complementarity.

On this basis I propose LIR as a preferred ontological logic of complementarity, and an '*LIRC*' as a theory of complementarity in which the PDO

plays the role of 'meaning principle'. One can then see the two types of theory of complementarity, *LIRC* and C_{mp}, as themselves complementary: the latter (on which much more in-depth work has been done), explicates an object level and a meta-level of statements about quantum phenomena, and the latter the corresponding levels of the phenomena themselves.

In conclusion, if the LIR PDO has a basis in physics, it should be taken into account in science and philosophy, including the philosophy of mind, either as an extension of complementarity or an as alternate description of 'complementary' phenomena. The argument is more complicated than in the case of complementarity based on paraclassical logic, but no less deserving of serious consideration.

7.5.2 Relational Quantum Mechanics

Relational Quantum Mechanics (Laudisa and Rovelli 2002) is an interpretation of quantum phenomena that discards the notions of the absolute state of a system, the absolute value of its physical quantities, or an absolute event. The theory describes only the way systems affect one another in the course of physical interactions. State and physical quantities always refer to the interaction, or the relation, between two systems. Nevertheless, the theory is assumed to be complete. The physical content of quantum theory is understood as expressing the ontology of the net of relations connecting different physical systems. In my opinion, this formulation has the strongest possible affinities with the principles of LIR, both from the point of view of the impossibility of absolute values or isolated events, and, what amounts to the same thing, the primacy of relations in a processual framework. Elements and events are not the 'material' terms of a relation, but are themselves always relations. Further, RQM leads to the idea that from the formal ontological standpoint, relations could be seen as a formal sub-category of Process.[17]

In standard QM, there is a core conceptual difficulty in reconciling the possibility of quantum superposition with the fact that the observed world is characterized by uniquely determined events. According to the theory, an observed quantity can be at the same time determined and not determined. An event may have happened and at the same time may not have happened. RQM offers a way out of the dilemma. QM becomes a theory about the physical description of observing and observable systems relative to other systems. This is a 'complete' description of the world that can be considered a kind of included middle between its observing and observable parts, the measured system *S* and the measuring system *O*. Rather than worrying about where to put a von Neumann

[17] In Whitehead (1978) the "concrete facts of relatedness" are classed as Prehensions among the categories of existence, while the "world as process" is the first category of explanation. One does not need to argue about the hierarchy here; what is important is the existence of a conceptual relation between relation and process.

'boundary' between the two, one focuses on their dynamic relationship. The comparison of accounts of different observers does not lead to contradiction because *the comparison itself is a physical process that must be understood in the context of quantum mechanics*.

The statistical features of correlations make their implications similar to those of relations. The relevant physics of a system *S* is entirely contained within the internal external correlations of its subsystems (which I believe are, always, what leads to '*S* '). It is to the correlations that physical reality may be ascribed, and not to the quantities that are the terms of the correlations. This can be compared with Lupasco's statement that "everything is determined by the relation, everything is relational, everything that exists, exists in relation to …" (Lupasco 1967).

This approach avoids the ontological multiplication of realities of the Everett 'many worlds' hypothesis that has had a certain attraction for some people. In the relational point of view, such epistemological abstractions are avoided, since physical quantities are uniquely determined, once two systems are given. It seems natural to suggest that it is a logic involving three and no more than three terms, which is appropriate for relational quantum mechanics. Relational interpretations can be given to aspects of special and general relativity, providing a more precise definition of time, and are consistent with the known observation that there is no absolute localization in space-time.

The relational approach weakens the notions of the state of a system, event, and the idea that a system, at a certain time, may have just a certain property. (In my view, that was what had to happen, namely, that the 'hold' of definitions of processes based on binary logic has to be weakened for progress to be made.) Laudisa and Rovelli say that despite wide diversity in the authors they cite, "there is a common idea underlying all RQM approaches, and the convergence is remarkable." The authors conclude by saying:

> This way of thinking the world has certainly heavy philosophical implications. The claim of the relational interpretations is that it is nature itself that is forcing us to this way of thinking. If we want to understand nature, our task is not to frame nature into our philosophical prejudices, but rather to learn how to adjust our philosophical prejudices to what we learn from nature.

Amen. I have tried to show here something of the nature and origin of those prejudices, in terms of the operation of the prevailing logic of identity and non-contradiction, and suggested how they might be overcome.

7.5.3 Quantum Physics and Consciousness

As an introduction to an eventual discussion of an LIR theory of consciousness, I wish here to discuss just one approach that has attracted much attention. Confronted by the indeterminate and determinate aspects of consciousness,

as well as the intuition we have of its being something fundamental in the universe, many people have sought to link it, and them, to quantum phenomena *directly*. One representation considered applicable might be a quantum wave function for the entire neural network that would be a superposition of the wave functions of its parts. Stapp and Penrose believe that it is the shared global character of conscious thought and quantum reality that makes the latter essential to the existence of the former. However, up till now, there has been no alternative to seeing, in the uncertainty of mental processes, the operation of the *same* physical principles as at the quantum level, views defended by Stapp and Hameroff. Thus, quantum mechanics would be applicable directly to beliefs, judgments, ideas, etc., which could be seen as quantum phenomena, despite excellent biophysical evidence that thermal noise results in total quantum decoherence (loss of information). In LIR terms, the relation between quantum and mental phenomena is the operation at both levels of the PDO in the isomorphic laws governing them.

Penrose's search for a missing science of consciousness, for a scientific understanding of consciousness, published in 1994, has by far not terminated. His intuition is one that I wholly share: there is an essential scientific ingredient missing needed to incorporate central issues of human mentality within a coherent scientific world-view (Penrose 1994). A picture of the universe requires an extension that does not only involve completion of the zoo of fundamental particles and their interactions, although it should be compatible with it. I have mentioned earlier the questions posed by the existence of quantum non-locality, but Penrose is in agreement that the strange world at the quantum level is real and permits real objects to be constructed from it. After showing that the simplistic approach based on activity at the microtubule level in the brain is inadequate, Penrose describes the missing physics as a "highly subtle non-computational (but undoubtedly still mathematical) physical scheme, an 'objective reduction' (OR). But what might be the source and nature of the 'OR effects' that could be "harnessed to conjure up the shadowy phenomenon we refer to as consciousness?"

As I claimed in connection with the naturalization of phenomenology, there is no reason to assume that consciousness as an emergent phenomenon requires different categories than other natural phenomena with the single exception of human individuation (the 'harder' problem), not of the behavioral aspects of consciousness.[18] This is not necessary in LIR, since the latter are described in terms of the contradictorial but physical process relations between the appropriate elements or entities. The burden of proof should be on idealists to show the basis of intentionality as being somehow outside physics, chemistry and cause-effect. This is not necessary in LIR, since the latter are defined in terms of the interactive processes between the appropriate elements or entities.

Penrose states that the way quantum mechanics operates is a (mathematical) mystery that appears to be the kind needed to accommodate mentality within physical reality, and that deeper theories will make the place of mind in the

[18] The 'hardest' problem remaining at this time is that of human individuation, why I am 'me' and not someone else, not the behavioral aspects of consciousness.

world less 'incongruous'. Most importantly for my LIR theory, Penrose says that *neither* a computational physics *nor* such physics augmented by randomness can be adequate. Rather:

> Every one of our conscious brains is woven from subtle physical ingredients that somehow enable us to take advantage of the profound organization of our mathematically underpinned universe …

The most important words in this citation: conscious, subtle, physical, somehow and profound organization all require explanation. As far as mathematical is concerned, Penrose' conception is that of a Gödelian mathematics, and suggest that the 'underpinning' is as much logical as mathematical, along the lines of the basic concepts of completeness and determinacy in Gödel's theorems.

The Gödel theorems and logic – as written – do not apply to physical or mental emergent phenomena, but LIR views the principle involved, the duality of consistency and completeness, axiomatically, as another instantiation of the fundamental duality of the universe. The current logical and ontological development undertaken in LIR provides a bridge between the PDO in the real world and Gödelian dualism. The relation between consistency (absence of internal contradiction) and completeness, in logic, language and mathematics, is between two abstract entities. For any application in physics or other science, what must be recognized is that an *isomorphic* relation of opposition or dynamic interaction can exist in the physical domain between real elements, processes, etc., with emergence of new phenomena as a consequence in certain cases.

In the next section, I will suggest further how the LIR interpretation of time and space modifies the metaphysical implications of theories about the universe.

7.6 TOWARD A LOGICAL COSMOLOGY

The logical conception of existence that I have proposed requires that the contradictorial physical and metaphysical relations for which I have developed a categorial ontology are justified by the basic physics of the world. All of the LIR concepts in hand of reality – being, continuity and determinism and their opposites – should be related to a description of the universe itself. As noted above, modern cosmology has developed in parallel with quantum mechanics, and the problems of reconciling a theory that applies to quantum objects and General Relativity that applies to large-scale gravitational phenomena are still very active topics of research. One can perhaps see the elements involved, the small and the large, as antagonistic in their characteristics of their extensity and intensity, the former as discussed in relation to limits exemplify action, discontinuity, and subjectivity, while the latter exemplify continuity, invariance, and mathematical extensity. However, much more is needed. In this section, I will discuss the relevance of some recent cosmological theories to the principle of dynamic opposition of LIR, and *vice versa*.

7.6.1 Space-Time in General Relativity

In Section 4.4.1 on the self-duality of the quantum field, I speculated on the relation of that duality to other dualities in physics and their correspondence with the picture of dynamic duality given in LIR. In this final section on physics, I will provide an interpretation of the other major component of existence, the phenomenon of universal gravity or the gravitational field.

One way of characterizing early 20th century cosmology is to say that it has been a cosmology of *identity* and non-contradiction, with major effort devoted by Einstein and others to a search for invariants. In special relativity, an absolute Newtonian time and space was replaced with a new invariant (the universal interval *s*). This approach gave a relative reality to time from which everything that depended on the observer was eliminated. The principles of Special Relativity (SR), pushed to its limits, essentially eliminated energy and dynamics from existence. General Relativity (GR) was introduced to handle the extension of relativity to non-uniform movement and microphysical phenomena, quantum and wave mechanics. For GR, Einstein proposed as the most general invariant the total curvature of the universe. This required a non-Euclidean geometry, from which all heterogeneity of its space-time points at a microscopic level was eliminated by the notion of bodies in continual acceleration (due to the curvature). In other words, through the requirement of general covariance (changes of position with respect to a frame of reference), these space-time points lost what in my view was critical, namely, the really and dialectically necessary component of *partial* individuation.

Two cosmologies were proposed to explain the relation between matter and space-time: the universe of Einstein, in which the geometric structure of the universe was determined by its total material mass. Finite, curved space-time was reduced to matter and absolute time, the absolute time "of the universe" was considered a sort of subjective noumenon with which no interaction could be possible.[19] In the Eddington-De Sitter model, there was no causal relation between the curvature and the total mass; matter was responsible only for local irregularities.[20] In the De Sitter model, a discontinuous intensity takes the position that

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[19] In work on new foundations for geometry and computation, Michael Leyton has criticized theories, from Euclid to Einstein, that maximize invariances on the ground that they are 'memoryless'. Leyton proposes the grounding of geometry on a concept of maximization of memory storage, that is, on shape. Leyton shows that certain shapes, described in a highly technical manner, contain a high amount of memory storage that can be organized in a hierarchy, called a *Process-Grammar*. Unfortunately, the dynamics of process seem to be missing in this otherwise wide-ranging rule system for inferring history from shape (Leyton 2005).

[20] Lupasco cites the strangely significant statement by Eddington: "*That which is* is an envelope that floats in the infinity of *that which is not*": two terms with the same ontological value, each defined by the other that opposes or negates it, and existence as a whole defined by both at once. This rather resembles the being and non-being of LIR.

extensity occupies as an external objectivity in the Einsteinian universe.[21] Both Einstein and Eddington seem to have avoided any *antagonistic* dualism, one throwing into the subject what the other threw into the object, and *vice versa*; for both one is appearance, the other reality.

Lemaître was the first to formulate clearly, in 1927, that the universe is in a phase of expansion, in which, accordingly, the matter of the Einsteinian model of the universe[22] that is becoming rarified, approaching the universe of De Sitter of pure geometric form. The Lemaître model reconciled the opposition between the first two models: there is a dual tendency to expansion and contraction, suggesting that a basic antagonism exists in the universe between the constitutive properties of this expansion and contraction. In the light of current cosmological work, the Lupasco picture of the universe of Lemaître is of interest: the dynamic opposition excluded in the other two models is maintained, and can be a source in principle of instability and becoming. I will now try to describe how this is done.

7.6.2 The Dual Role of the Metric Field

As discussed above, Special Relativity (SR) describes an absolute chrono-geometrical structure of a four-dimensional Minkowski universe with a Euclidean geometry in which is embedded a frame-relative, observer-dependent space-time. 'Distant' simultaneity is defined by convention. General Relativity (GR) is necessary to handle the universal nature of gravitational interaction and aspects of physics at high energies. However, this theory removes all physical objectivity from space-time, and is in direct conflict with the 'apparently real' objectivity of the phenomenological world. There is, accordingly, a need for some kind of frame- and observer-independent description which would ground both the reality of both experience and scientific knowledge. The debate revolves over how to assign physical meaning to the *metric field* which is the central concept in GR. The metric field is a term for the mathematical (tensor) description of the geometrical and gravitational structure of the universe as a four- (3 + 1) dimensional space-time manifold – the background for, but also possibly a participant in the manifesta-tions of physical events.

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[21] Eddington was credited by Lupasco for having seen how much *his* view of the constitution of the universe was a creation of his mentality, a "universe in his image". Eddington never seems to have wondered explicitly about the equally 'logical' opposite view, nor that there might be something very fundamental indicated by this conflict.

[22] Coherent interpretations of the phenomenon of time and the nature of space-time are being currently sought in terms a synthesis of gravity and quantum field theory. The theory of Yilmaz (Alley 1995), for example, corrects certain oversimplifications made by Einstein, and suggests solutions to a number of problems, in particular, the absence of a basis for Newtonian interactions in General Relativity, a need recognized by Einstein himself.

The solution proposed by Lusanna and Pauri (2005) starts by seeing the metric field as split into two parts: an ontic part corresponding to the autonomous degrees of freedom of the gravitational field in the absence of matter, and an epistemic part to the information encoded in the metric that must be specified in order to get empirical access to the ontic part, which refers to the appearance of gravitational phenomena.

A physical individuation of point-events is derived in terms of the ontic part of the gravitational field. The identity of point-events is conferred upon them by a complex relational structure in which they are holistically enmeshed. This relational structure includes all the elements of a so-called complete gauge fixing, supported by a definite solution of Einstein's equations (a definite Einstein "universe"). The characterization of such space-time points includes the fundamental intrinsic properties instantiated at those points including mass, charge, spin and perhaps others. However, it also gives a physical meaning to the coordinate indexing of such which makes point-events as ontologically equivalent to the existence of the gravitational field as an extended entity.

Summarizing, this view holds that space-time point-events do exist as individuals however, their properties can be viewed both as extrinsic and relational, being conferred on them in a holistic way by the whole structure of the metric field and the extrinsic curvature on a simultaneity hyper-surface (see below), and, at the same time as intrinsic, being coincident with the autonomous degrees of freedom of the gravitational field. "In this way both the metric field and the point-events maintain their own manner of existence, so that the structural texture of space-time in this model does not force us to abandon an entity realist stance about both the metric field and its points". This theory supports LIR since for the above description of time and space no background of *dimensionless* points (like those of differential calculus) needs to be postulated in addition to, or apart from, either the causally effective quantum field or the gravitational field and their self-duality.

Here, the thesis according to which metrical relations can exist *totally* without their constituents (point-events as relata, some of which may be relations; this point remains open) does not hold. LIR is consistent with this physics that provides a basis for a physical individuation of *some* point-events (entities), while insuring the required indistinguishability of quantum particles. LIR insists on a contradictional relation between identity, which implies indistinguishability, and diversity, which implies individuation.

Lusanna and Pauri (2006) propose solutions to Einstein's equations in which there is a dynamical emergence of 'instantaneous' 3-spaces, the three-dimensional instantaneous spaces in which ordinary phenomena are observed and described. In their striking metaphor, 'space-time' and the vacuum (matter/energy free) gravitational field are "two faces of the same reality". The 3-spaces are 'embedded' in an Einsteinian 4-D manifold. The appropriate theory is a new kind of structuralism, containing with elements of both the substantivalist and relationist points of view, implying a four-dimensional holism resulting from a foliation or unfolding within it of the instantaneous spaces with three spatial coordinates (3-spaces). The reality of the vacuum space-time of GR, the dynamical

instantaneous 3-spaces and their dynamical individuation of point-events described by the epistemic part of the metric field is ontologically equivalent to the reality of the autonomous degrees of freedom of the gravitational field as described by the ontic part of the metric field. What this study brings out is that GR contains the potential for a differentiated description of both the four-dimensional space-time manifold implied by the existence of universal gravitation and a 'foliation' development into 'sheets' of observable 3-spaces.

In this picture, the individuation of the point-events involves their change in time. This is an attribute whose information is not wholly contained in the 3-space at a time *t*, but this is not inconsistent with the dual role of the metric field in GR. That a complex material process entity cannot be described as *wholly* present or absent is logically acceptable in LIR, and I see here a basis for the eventual formalization of the LIR conception of simultaneity and succession.

The program of Lusanna and Pauri thus establishes the mathematical basis for a reinterpretation of a 'join' region between phenomenal and non-phenomenal reality, establishing a relation that is both physical and epistemological (Smith 1997). LIR is compatible with this interpretation, which can serve as an extension of its foundation in physics as foreseen in Section 4.5.2. I wish to emphasize that I am not endorsing this theory as the last or most authoritative word on models of General Relativity; this is not a monograph of physics. The program is, however, a basis for discussion that not only addresses the complex relations between space-time in general relativity and phenomeno-logical space-time, but also discovers relations in the physics that have dialectic properties that LIR is capable of formalizing axiomatically and categorially. The usual counterarguments are available, but I submit that the alternative of seeing the two theories as mutually supporting is worthy of consideration.

From my point of view, the Lusanna and Pauri description suggests that the underlying *principle* of the metric field is one of self-duality, expressed by the properties of the gravitational field alone, which the authors describe as more ontologically diverse than any other. The critical insight is that GR is a theory that from the physical point of view is radically different. Its reference is to the space-time that evolves 'within' the gravitational field rather than to some internal mathematical groups, and it leads to a dual role of having both a unique dynamics (reality) and appearance to an observer.

Self-duality in cosmological theory refers to a type of solution to Einstein's equations,[23] for which LIR suggests a physical interpretation in terms of the same kind of opposition between inherent properties as in the quantum field. This view is supported by Majid's principle (Majid 1991) of representation-theoretic self-duality which states that a fundamental theory of physics is incomplete unless the role reversal implied by duality 'pairing' of structures is taken into account. The self-duality condition means that an evaluation function f(x) can also be read x(f) where f is an element of a dual structure. The consequence is that since all the reality elements of LIR are dual, they follow this principle, as does the notion of T-duality in string theory referred to in Chapter 4. This form of

[23] For a general discussion see van Holten (1996).

self-duality was shown by Majid to apply to quantum theory and gravity theory, since Lie groups provide the basis for both the Riemannian (non-Euclidean) geometry needed for a representation of gravity and the quantum numbers of elementary particles in quantum theory. Also interesting from my point of view is Majid's search for an appropriate axiomatization of this principle, *via* an extension of intuitionist logic to a 'co-intuitionist' logic[24] to try to capture the duality. LIR, of course, starts from the position that duality is in any case ontologically primitive, and the relations can be expressed in contradictorial terms of alternate actuali-zation and potentialization of the elements. The necessary change to the law of the excluded middle falls out naturally.

The concept I suggested above of objects (matter/energy) being the source of space-time, or space-times should now be augmented as follows: the gravitational field exclusive of matter/energy has the physical role of individuating, physically, the points of a four-dimensional manifold. The gravitational field is constituted by gravitons or instantons, considered as quantum particles with a very high quantum number. In another metaphor of Lusanna and Pauri that I see as an expression of the self-duality of gravity, these non-linear gravitons are at the same time "both the stage and the actors within the causal play of photons, gluons, and other material (energetic) characters such as electrons and quarks".

7.6.2.1 Simultaneity: A Comparison of Dynamics

The issue of simultaneity of events offers a good opportunity for comparing its description in general relativity and *via* the logic of/in reality. In Section 7.2.3, the origin of simultaneity and succession was proposed as a matter of *logical necessity*, given some minimum assumptions about being and change. Simultaneity and succession were linked dialectically, as operations defining non-formally the space and time respectively associated with two entities, without reference to distance or proximity. However, the effect of the universal gravitational field has not been taken into account explicitly.

The account that is emerging in GR yields an image of a complex curved 'surface' (hyper-surface, which may be asymptotically 'flat') of simultaneity on which are located point-events throughout the universe. The advantage of this picture is that it corresponds to the intuition that distant events *are* simultaneous with proximal ones, despite the inevitable ignorance of the clock-time at such events. The advantage of this model over that of Special Relativity is that it is dependent on the definition of a global, non-inertial frame of reference but this is the same for all observers. All have the same sequence of before and after, and the same notion of simultaneity and perceived instantaneous 3-spaces (space not 'flowing' as time).

[24] This is in fact a form of paraconsistent logic.

One can differentiate the descriptions by referring to the respective meanings of dynamics and dynamically: in the LIR 'metaphysical' model, dynamic in dynamic opposition refers to the real physical interactions between any entity and its opposite or negation resulting in an alternating potentiality and actuality of both. Where those are absent, as in the case of three billiard balls, there is no question about their all being on the table 'simultaneously'. In the GR model, as in some forms of structural realism, dynamic refers to a principle of change inherent in the *equations*, Einstein's or others, which describe a non-trivial evolution in 'time'. These are referred to as 'dynamic symmetries', dynamical tensor fields and so on. All of the chrono-geometrical structure of an Einsteinian universe is dynamically determined in this sense. The point-events located on the simultaneity surfaces are achronal (timeless *per se*), but are characterized by dynamically determined conventions about distant simultaneity. My conclusion is, however, that simultaneity in GR is still defined as a *convention*, with respect to such large distances. There is no explicit reference to the simultaneity or lack of it in proximal events that may be in just as much need of definition.

The major difference in the LIR and GR accounts of simultaneity is in thus in their treatment of *proximal* events involving entities of greater tangible complexity than those at the quantum or cosmological levels. Another way of saying this is that wherever the process phenomena require formalisms for their description that are dual in the LIR sense, but not self-dual as in the case of quantum and gravitational fields, the LIR picture applies. The logic I have proposed describes the contradictorial evolution of biological and cognitive processes as involving a richer structure of simultaneity and succession than provided by GR.

Having arrived at a *logical* theory of time and space, or space-time, it might be asked what possible consequences it might have, practical or theoretical. I suggest two preliminary answers: first, this logic could make more accessible, by pointing to the operation of the PDO in them, the contrasting or opposing domains of cosmological physics. It is, if one likes, a restatement of the fundamental duality of the universe into perceiving and non-perceiving domains. The mathematical and physical structures of these domains are separately describable but functionally linked as suggested by the LIR axioms of LIR, in particular, of Functional Association, Conditional Contradiction and Asymptoticity. Second, it could serve as another way of reminding people that the space and time they experience are neither eternal and absolute realities, nor the framework of *a priori* functions of sensibility, but the consequence of the existence of matter/energy itself.[25] The further role of LIR may be, given the application of the PDO 'across the board', to facilitate the application of significant aspects of the new theories at the quantum and cosmological levels of reality to the levels of intermediate biological and agentive human existence.

[25] Lupasco's phrase was: "the continual creations of the contradictory, deductive fertility of energy."

7.6.3 Structural Realism and the Metaphysics of Relations

The reason for returning to the discussion of structural realism and the role of relations in it is to examine its physical significance, now that the significance of relations has been established for the most fundamental physical theories. Both quantum field theory and General Relativity describe the relations involved in quantum entanglement (non-separability) and space-time respectively. In the above discussion of cosmological physics, I have tried to give some sense of its evolution and suggested that the improvements that are being made in the above are due in part to the descriptions of gravity and the duality and self-duality of energy (the quantum and gravitational fields) that bring out the inherent duality in existence.

A metaphysics of relations was developed by Lupasco in his monograph on structure (1967) cited earlier: he said essentially that objects can neither appear (to us) nor exist except as a elements related to others. Everything is relational; nothing is self-sufficient. There is a 'law' of contradictory relationality, *whose terms are indefinitely relations* (emphasis mine), that governs or implies the contradictional antagonism of the homogeneous and heterogeneous, the same and the different, and so on. The two essential relations in the LIR theory are those necessary for the formation and continuing existence of a minimal physical system, as described in Appendix 2. They are: (1) the relation of antagonism or opposition, whose elements are attraction and repulsion; and (2) the relation of contradiction, whose elements are identity and diversity, homogeneity and heterogeneity. These are related to, or the expressions of, the fundamental duality in energy in which the relations are intrinsic or internal. The relational aspects of LIR were also mentioned above in connection with Relational Quantum Mechanics (RQM), where I pointed out that the relational approach weakens the notions of the state of a system, event, and the idea that a system, at a certain time, may have just a certain property. This was in part the basis for my critique of the pure logical approach to being of Jacquette in Chapter 3.

There is a striking similarity between the Lupasco view of the fundamental nature of relations and that of Ladyman and Ross outlined in Chapter 6. The later authors maintain a metaphysics of structural realism (Ontic Structural Realism, OSR) according to which there is, primitively, structure in the sense of concrete, physical relations, with objects derived from relations. LIR gives a picture of this 'derivation' in terms of a pause in the ortho-dialectic concatenation of processes (Appendix 1). The ontological commitment to relations in LIR and OSR, as well as RQM places objects and their relations on the same level within a holistic metaphysics.[26] Esfeld sees our world as one of holism, tied together by relations that do not supervene on (whose source is not) intrinsic properties. There is no ontological priority, but rather a mutual ontological dependence between space-time relations and the objects that stand in the relations, considered as

[26] Esfeld and Lam (forthcoming).

space-time 'points' or point-events as developed in the theory of Lusanna and Pauri. These point-events also define the process entities which LIR sees as populating the universe, instantiating both identity and diversity.

This view holds that when space-time point-events are the relata, they do exist as individuals. Their properties can be viewed both as extrinsic and relational, and, at the same time, as intrinsic. The concept that point-events instantiate both intrinsic and extrinsic properties at the same time fits the category of Dynamic Opposition. Whether or not relations by themselves, at this primitive level, can be described in this picture as real entities capable of entering into relations with others is not clear. At any other level, if they are involved in an energetic interaction, the LIR description is that they (the relations) are real but both actual and potential.

I referred earlier to the debate between substantivalists who consider that matter exists either distinct from or equivalent to 'space-time' and relationists who insist that all there is to fundamental physical objects is the relations in which they stand. In relationism, the physical meaning of space-time depends upon the relations between bodies; its specific reality is dependent of the entities or fields present. The above view of space-time, called point-structuralism, includes elements common to both substantivalism and relationism. Lusanna and Pauri believe their analysis may offer a *tertium quid* resolution of the debate by overcoming it (in LIR terms, a solution emerges from the dialectics as an 'included' third term: *tertium datur*). It is the kind of best-of-both-worlds scenario which LIR sees as logical *via* the principle of dynamic opposition and the category of Non-Separability of entities at all levels of reality.

In this "peculiar space-time structure", the relation/relata correspondence does not fit either of the extreme views: the totality of the physically concrete events is displayed by means of the holistic relational structure. In LIR terms, this structure is a 'structuring' since it is the source of the points which supervene on it. The points of general-relativistic space-times, unlike the points of homogeneous Newtonian space, have a rich non-point-like, holistic structure furnished by the metric field. Although physical properties are conferred to the point-events in a peculiar relational form, point-structuralism does not support the standard relationist view either. Point-events are individuals, albeit in a peculiar sense: they exist as autonomous constituents, but one cannot claim that their properties do not depend on the properties of others. Not only relations exist, but also the carriers of them, even if their intrinsic properties are also relations. This is another statement of the LIR position on individuality. It provides further support for the extension to higher levels of reality, since the relations (say, between human individuals) can readily be seen to be both dependent on and independent from the individuals themselves.

Esfeld maintains that the distribution of relations can be contingent in the same way as the distribution of intrinsic properties. Laws of nature, as in a Humean world, can be contingent instead of metaphysically necessary. The LIR version of structural realism also does not require that locally necessary relations invalidate global contingency, since it assumes the existence of domains and entities

that are not linked dynamically, as well as those that are. Situations of interest in the macroscopic world, however, will generally exhibit contra-dictorially linked aspects of both necessity and contingency, as discussed earlier.

From my metaphysical standpoint, what is essential in the above is the mutual ontological dependence between relations and objects regardless of what the relations are (quantum, spatio-temporal, or interactive) and of what the objects are (single quantum systems or complex space-time point-events that are equivalent to macroscopic processes). In my view, this dependence is described logically by the axioms of LIR and its fundamental principle of dynamic oppo-sition. Stated more specifically than in Esfeld, any relation is part object and any object is part relation such that one is more instantiated at any time at the expense of the other, physically and theoretically, except at the mid-point of the interaction that, above the quantum level, is the locus of emergence. At the most fundamental level of reality or being, one would, in this theory, still never find a single object 'existing', but a minimum of two plus their relation.

7.6.4 A Cyclic Model of the Universe

One debate in cosmology, as discussed in Chapter 4 and above, revolves around the nature of the gravitational field and/or the reality of strings as fundamental entities of which the universe is constructed. One might regard the former as evidence of a general trend toward more balanced solutions in which dynamic opposition is present and the latter – string theory – as the latest version of a continuing tendency toward a cosmology of identity. The cyclic model of the universe discussed below is for me an example of the former.

Models of the universe since the original concept by Lemaître of an expanding universe have assumed an initial singularity, the Big Bang, at, or as, the origin of the universe, in which matter-energy had 'infinite' temperature and density. The weakness in this picture is the existence of the singularity, how it can possibly be explained, and, if, as some versions of this model require, the Big Bang is followed by a phase of contraction, what meaning is to be ascribed to the Big Crunch that would necessarily follow.[27]

The consensus regarding the current state of the universe is (1) that it is expanding at an increasing rate; and (2) it seems to be composed to the extent of 70% of an unknown dark energy, 25% of cold dark matter, whose nature is also unknown, and of not more than about 5% of ordinary matter-energy. I have selected the model proposed by Steinhardt and Turok (2002) as an illustration of

[27] I will not discuss here the endless speculation of how such a notion can be reconciled with the experiential notions of time and space (what 'was' before the Big Bang). These questions are applicable only to the veiled three-dimensional view of reality that is possible to us as medium-sized macroscopic objects, and, as indicated, probably badly posed.

what a theory based on categories of Energy, Process and Dynamic Opposition might look like.

In this cyclic cosmological model, the universe undergoes an endless sequence of cosmic epochs that begin with almost a 'bang' and end in almost a 'crunch'. Temperature and density at the transition remain finite. Instead of having an inflationary epoch, each cycle includes a period of slow accelerated expansion (as currently observed) followed by contraction that "produces the *homogeneity* (emphasis mine), flatness and energy needed to begin the next cycle." Steinhardt and Turok showed that the universe is infinite and flat, rather than finite and closed as in earlier oscillatory models, and no singularities are required. A negative potential energy is introduced rather than spatial curvature to cause the reversal from expansion to contraction. The authors also suggest a mechanism for the passage from the end of contraction to the restart of expansion: some small fraction of the kinetic energy is converted to matter and radiation, but both sides of the relation involved are finite at the 'bounce'. In LIR terms, a potential is available to effect the changes. Subsequently, the scalar field increases rapidly, but its motion is damped by the expansion of the universe and comes to rest prior to the next phase of expansion, in a movement that reminds one of actualization and potentialization. The universe never reaches a true ground state, but 'hovers' above it, approaching asymptotically now one side and then the other of the cosmic potential well. The serious metaphysical problem of a putative 'first cycle' is not explained in this model, but the situation is no worse than in any other. In further theoretical work, the authors show that the cyclic model gives a possible explanation for the low relative value of the cosmological constant. This picture offers, among other things, more stages of evolution of the universe in which the constants would be appropriate for life (Steinhardt and Turok 2006) than does the standard Big Bang model. This eliminates a bothersome 'epistemological singularity', since in combinations of the strong anthropic principle (see Chapter 1) with an inflationary cosmology, the fraction of space-time that is 'habitable', that is, available for life, is infinitesimally small.

It is of interest to note that serious researchers have been arrived at a cosmological description that tracks the basic principles of LIR quite closely. It is one of the key aspects of my approach that singularities, or the artificial idealized limits between opposing terms that are required by Aristotelian logic, do not in fact exist. It will be fascinating to see whether further discoveries about the nature of dark matter and energy and negative gravity, perhaps based on the cyclic model, will provide more direct illustrations of the principle of antagonism. This theory has been challenged by a proposal that the expansion of the universe is a by-product of enormous ripples in the fabric of space-time. These ripples, caused by rapid inflation after an alleged Big Bang, mimic in this second theory the properties of dark energy. One has recourse to a series of hypothetical constructions that are separate identities – the ripples, the Big Bang and a background fabric of space-time – all of which embody concepts of time, space and causality from classical logic. Despite its theoretical and mathematical complications, this theory describes static entities, the idealized products of processes in which they do not participate. Accordingly, I will hazard the prediction that based on the

principles I have been talking about, the cyclic model, in which one can see the operation of a dynamic opposition, an alternating actualization and potentialization, is closer to being correct.[28]

In the next and final chapter, I will look at the application of all the logic and concepts developed so far to the biological level of reality.

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[28] A number of recent *Gedankenexperimente* suggest additional potential real-world implications of LIR. For example, Gingrich and Adami (2002) show that particles whose spins were entangled when at rest lose spin entanglement when accelerated to relativistic speeds, their momenta become entangled to compensate, and *vice versa*. In LIR terminology, actualization of momentum entanglement potentializes spin entanglement.

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