Duality : A Bridge Between Physics And Philosophy?*

A. N. Mitra †

March 31, 2022

Abstract

A generalized view of Duality is offered as a bridge between physical sciences and the more abstract philosophical dimensions bordering on mysticism. To that end several examples of duality are first cited from from conventional physics sectors to illustrate the obvious powers of this principle. These include items from reciprocity in Newtonian mechanics to the problem of measurement duality that characterizes quantum mechanics. It is also noted that the latter has acquired a renewed interest in recent times, consequent on the emergence of new experimental techniques for testing the actual laboratory outcomes of traditional gedanken experiments, hitherto taken for granted. Against this background, the Duality principle is sought to be extended to the mystical domain, with convincing examples from various human level experiences.

1 Introduction

The year 2005 that has just ended, witnessed the centenary of Einstein’s 1905 revolution that changed the entire face of Physics. And now comes 2006 which is of special significance to this country, namely, the birth centenary of D.S. Kothari, a philosopher scientist who played a key role in directing the course of science in Independent India, by stressing the “value system” that goes with it. Therefore in tune with his value-based philosophy, it is perhaps appropriate to choose the theme of this article as Duality, since it touches on both aspects of knowledge, namely physics and philosophy. The idea is not completely new, since I had written a similar article 20 years ago, on the occasion of his eightieth birthday [1]. While the theme of the present article overlaps with that of [1], and I shall draw freely from [1], the relative emphasis nevertheless warrants a fresh presentation of the Duality theme.

Now the traditional implication of Duality in physics concerns the incompatibility of measurement of two canonically conjigate variables. However, in tune with [1], it is both necessary and sufficient to give an extended meaning of this magic word to cover several other sectors of physics as well. To that end, we identify as many as FIVE distinct facets of duality in physics, namely: Reciprocity; Parallelism; Alternative formulation; Synthesis; and of course Measurement incompatibility.

2 Aspects of Duality in Physics

We give in this Section some illustrative examples of the first four kinds of Duality in Physics, leaving the (more involved) fifth one for the next Section.

2.1 Reciprocity (Mutuality) Aspect

For certain situations, the mathematical equations suggest a sort of mutuality or reciprocal relationship between the dual partners. We list three examples [1], each of which implies a deep underlying symmetry in the corresponding physical situation. The first relation is

\[ \vec{A}(\text{action}) = -\vec{R}(\text{reaction}) \]

The symmetry implied by this relation is that the mutual potential energy of any two bodies is an invariant function of their relative distance, and not of their absolute positions. The next one is from

*This article is dedicated to the memory of Prof D.S. Kothari on his birth centenary.
†e.mail : ganmitra@nde.vsnl.net.in
Maxwell equations in vacuum:
\[
\nabla \times \mathbf{E} = -\partial_t \mathbf{B}/c; \quad \nabla \times \mathbf{B} = \partial_t \mathbf{E}/c
\]

Such a reciprocal relationship between the electric and magnetic vectors was conjectured by Maxwell to bring out the full symmetry of their mutual interdependence, which in turn is essential for current conservation, while the tiny ‘displacement current’ (detected later) was a byproduct of Maxwell’s deep insight into inter-relationship between the two vectors. A third relationship of this kind stems from the Hamilton’s equations of motion in terms of canonically conjugate variables \((p, q)\):
\[
\partial_p H = dq/dt; \quad \partial_q H = dp/dt
\]

These equations, whose physical content is strictly confined to Newton’s original laws of motion, bring out rather convincingly the reciprocity of the roles of the \(q\)- and \(p\)-variables, a feat achieved through Hamilton’s penetrating formulation of the laws of Newtonian mechanics, which was subsequently to pave the ‘golden road to quantization’ [2] at the hands of Heisenberg and Schroedinger.

More examples of mutually inter-dependent pairs may be found from the mathematical theory of transforms (Fourier, Hilbert) which reveal such relationships (together with their diverse physical consequences) in a most succinct manner. Thus while the theory of Fourier transforms is at the root of duality between coordinate space \((x)\) and wave number space \((k)\), Hilbert transforms illustrate the value of analyticity in the complex plane in bringing out the inter-relationship among the real and imaginary parts of a scattering amplitude. There are many such duality relationships in physics.

### 2.2 Parallelism (Analogy) Aspect

The analogy aspect is best illustrated by Fermat’s principle for optics, versus Maupertius principle for mechanics:
\[
\delta \int \mu ds = 0 \iff \delta \int p ds = 0
\]

This close parallelism between the respective laws between two widely different branches of physics was to play a crucial role in Schroedinger’s formulation of wave mechanics from its classical ”ray” (\(\hbar \rightarrow 0\)) picture, as the mechanical analog of wave vs ray optics.

A brilliant example of the parallelism aspect of Duality is expressed by a profound correspondence between classical and quantum mechanics in the form
\[
\{A, B\} \iff \frac{1}{\hbar}[A, B]
\]
discovered by Dirac during one of his long evening walks in his early Cambridge days [3]

### 2.3 Alternative Formulation Aspect

Still another feature of Duality concerns the formal equivalence of certain alternative formulations apparently unrelated to each other, yet having the same physical content. The Heisenberg vs Schroedinger formulations of quantum mechanics represent precisely such a physical situation. Although their equivalence is now text-book material, their apparent dissimilarity at the initial stages of formulation had catalyzed the polarization of two strong schools of thought [4], viz., i) Heisenberg’s algebraic approach emphasizing the corpuscular aspect characterized by discontinuity; vs ii) Schroedinger’s analytic approach in terms of a wave equation stressing the elements of continuity [1]. Subsequently it was found that the two approaches differed only by a unitary transformation!

A dramatic manifestation of the alternative formulation aspect showed up in the orthodox Tomonaga-Schwinger (field theoretic) versus the highly unorthodox Feynman (diagrammatic) formulations of covariant quantum electrodynamics. The two formulations looked widely different, but it was Dyson’s catalytic role which reconciled the two when he [5] derived the Feynman diagrams from the premises of the Tomonaga-Schwinger formalism. And later, the traditional rivalry between Feynman and Schwinger showed up even more acutely in terms of Path Integral formalism [6] of the former, versus Source Theory [7] of the latter, even though the respective contents are basically identical!

At a more impersonal level, a good example of the complementary aspect of Duality is afforded by the empirical finite energy sum rules (FESR), wherein the contributions to a high energy scattering
amplitude by the direct s-channel resonances are supposed to saturate the corresponding contributions from the exchange $(u,t)$ channels [8]. This form of duality led to the Veneziano model [9] which received considerable refinements at various hands (Harari, Rosner, Fubini et al), eventually giving rise to Nambu’s String Model [10], that was the forerunner of the modern theory of strings.

### 2.4 Synthesis (Unification) Aspect

A major aspect of Duality, relating to the synthesis of certain pairs of physical concepts, is embodied in the theory of relativity which provides an integrated view of the space-time continuum, as opposed to the Newtonian ‘partition’ of their respective foundations [1]. The parallel concepts of wave-vector & frequency; momentum & energy 4-vectors are linked to space-time by Fourier transforms and canonical conjugation respectively. On the other hand their direct link is provided by quantum theory:

$$p = \hbar k; \quad E = \hbar \omega$$

The situation is illustrated in Fig 1.

A dramatic manifestation of the unification aspect of Duality is the prediction of antimatter as a result of the successful marriage of the dual partners represented by Relativity and Quantum theory under the auspices of Dirac who effectively showed that the marriage is not possible at the level of single particles, but only in the collective context of particles and antiparticles; in other words, in a field theory [11].

As a final example of the unification aspect of Duality, the concept of Supersymmetry [12] purports to project an integrated view of bosons and fermions, hitherto believed to be two distinct fundamental species, totally unrelated to each other. The Bose-Fermi symmetry or SUSY, as this new theory is called, has some highly attractive theoretical features, like an ability to cure some vexing problems of infinities, but its predictions are yet to find experimental support. The theoretic investment in this field has been extremely rich in recent years, with allied developments in Supergravity, superstrings, and so on, but there has been almost zero development on the (dual) experimental front. Table 1 below gives a list of the various dual partners in physics, discussed in the foregoing.

### 3 Measurement Aspect of Duality

Finally we come to the most important (quantum mechanical) aspect of Duality, namely, the incompatibility of measurements of certain pairs of dynamical variables known as canonically conjugate pairs,
Table 1: Dual partners (physics items)

| I-Member          | II-Member          | Legend/Ref.     |
|-------------------|--------------------|-----------------|
| Action (A)        | Reaction(R)        |                 |
| Coordinates (q, θ)| Momenta (p, J)     | Hamilton, Jacobi|
| Electricity       | Magnetism          | Faraday–Maxwell |
| **E, B**          | **D.H**            | Cause vs effect |
| Pressure, stress  | Volume, strain     | Cause vs effect |
| Time (t)          | Space (r)          | Einstein’s relativity |
| Energy (E)        | Momentum (p)       | Relativity      |
| Energy (E)        | Mass (m)           | Relativity      |
| Fermat principle  | Maupertius principle| Parallelism   |
| δ ∫ μds = 0       | δ ∫ pds = 0        | Optics vs Mechanics |
| electromagnetic wave | Photon           | Planck          |
| e− - wave         | Electron           | de Broglie      |
| Schroedinger (wave mech)| Heisenberg (matrix mech)| Alternative formulations |
| Feynman path integral | Schwinger Source theory | Language duality |
| Resonances (s-channel) | Exchanges (t u channel) | FESR duality ( ref. [8] ) |
| Observer ( macro appara- tus) | Observable (micro system) | Bohr’s duality |
| Boson             | Fermion            | Supersymmetry   |

...together with their derivatives. This shows up as the famous Uncertainty Principle of Heisenberg, which is mathematically derivable from any consistent form of quantum mechanics (Heisenberg, Schroedinger), in the form:

\[ \Delta q \cdot \Delta p \geq \frac{\hbar}{2}; \quad \text{if } [q, p] = i\hbar \]

Although a strict mathematical consequence of the tenets of quantum mechanics, the physical significance of the Uncertainty Principle (UP) is nevertheless profound enough to touch instantly on the philosophical plane. For one thing, it succinctly reveals the paradox of the wave-particle duality which is profoundly disturbing inasmuch as it goes against all norms of "classical justice". For another, the nature of a ‘gedanken experiment’ by which the effects of the UP is sought to be projected, happens to be such as to preclude the possibility of simultaneous observation of two canonically conjugate variables in the same experiment. Indeed, any attempt to measure the second variable in an experiment designed to observe the first, will result in a destruction of the property of the former, and vice versa! This limitation transcends either the quality of the experimental apparatus or the extent of the human ingenuity in designing the experiment, since it stems directly from the mutual interaction between the observer (apparatus) and the observable (the physical property under study). To make contact with the corresponding ‘classical’ situation, the effect of this interaction is negligible on a macroscopic entity, but non-trivial on a microscopic one (of atomic dimensions), so much so, that an accurate measurement of one its attributes precludes a simultaneous knowledge of the canonically conjugate one.

The last aspect of Duality has no counterpart in the other four categories listed earlier, since there had been no reference to the quantum limitation in any of them. Now the measurement incompatibility problem is a typical quantum effect, which introduces a characteristic ‘duality’ situation that has no classical counterpart. And several of the pairs considered in the foregoing will suffer the measurement limitation if viewed from a quantum mechanical angle. A good example is afforded by the ‘reciprocity related’ variables \( E, B \) which indeed suffer the measurement incompatibility problem when viewed quantum mechanically, using the idea of ‘test charges’ for their measurement [13].

### 3.1 The Copenhagen Interpretation

The Copenhagen Interpretation, which is based on Bohr’s view of Duality, is concerned with the problem of observer-observable interaction at the quantum level. In a lecture at the International Physics Congress at Como in 1927 [1], he introduced the principle of *complementarity* to reconcile the characteristic features of individual quantum phenomena with the observational problem “in this field of experience”. In particular, he emphasized "the impossibility of any sharp separation between the behaviour of atomic
objects and their interaction with measuring instruments which serve to define the conditions under which the phenomena appear" (quote from Bohr [1]).

This physical picture, which was Bohr's response to the mathematical content of the UP, was fully in consonance with the deep insight which had marked his stewardship of atomic physics since its nascent beginnings early in the last Century. In contrast, the absolute Wave Function approach of Von Neumann [14], whose adherents included stalwarts like Wigner, Everett, Wheeler and de Witt (see ref [1]), advocated the use of a master wave function which included the wave functions of both the (microscopic) system under observation, and that of the (macroscopic) measuring apparatus. Without going into the elaborate rules governing the interaction between these two systems [15], the Copenhagen Interpretation takes an intensely pragmatic view of the concept of 'truth' ( a la William James ?), as may be summarized in the following two statements:

(a) The quantum theoretic formulation must be interpreted pragmatically [1] ;
(b) Quantum theory provides for a complete scientific account of atomic phenomena. The pragmatic aspect has found expression in numerous thoughts and writings of Bohr on the measurement process itself (for details, see ref.[15]). The 'completeness' aspect of quantum theory is more subtle, and gave rise to the Bohr-Einstein debate. Bohr’s point of view in this regard is aptly summarized by Stapp [15]. Namely [1], the well-defined objective specifications on a given phenomenon under study are not restrictive enough to determine uniquely the course of the individual processes, yet no further breakdown is possible because of the inherent wholeness of the process symbolized by h. This 'wholeness' has no classical analogue which would have recognized the measuring instruments and the atomic objects as separate entities. Instead, the inseparability of the atomic object from the entire phenomenon renders a statistical description unavoidable. This way of reconciling the pragmatic character of quantum theory with the claim of completeness, is based on "quantum thinking". Its ultimate validity must be judged by its a fortiori success which includes coherence and self-consistency.

3.2 EPR paradox and Bell’s Theorem

What was Einstein's reaction to Bohr's philosophy? It was one of profound unhappiness [16] with such claims of "completeness" of quantum mechanics! Compare the above picture with the tenets of classical realism, namely, (a) all physical attributes of an individual object have definite values associated with them at any instant of time, irrespective of their actual (non-invasive) measurement; (b) a commonsense concept locality which allows us to deal with the external world in a piecemeal fashion, not all at once. Now look at the situation in quantum mechanics: if two systems have once interacted together, and later separated (no matter how far), they can no longer be assigned separate state vectors. A famous example is a spin-zero object at rest, breaking up spontaneously into two fragments with spins S1 and S2 respectively, moving in opposite directions. Now conservation of angular momentum demands that the two spins be equal and opposite, so that any measurement of, say, S1 will automatically fix the value of S2, even without an explicit measurement. This situation goes much against intuition, since a physical interaction between these two objects, receding far away from each other, is negligible. And this was the bone of contention of the EPR paper [16] on this paradoxical aspect of quantum mechanics. EPR [16] sharpened the issue further by introducing two definitions [17, 18]: i) a necessary condition for the completeness of a theory is that "every element of the physical reality must have a counterpart in the physical theory"; ii) a sufficient condition to identify an element of physical reality is "if in any way without disturbing the system, we can predict with certainty the value of a physical quantity, then there exists an element of reality correspondity to this physical quantity". The result of these considerations was the EPR Theorem [16], viz., the incompatibility of the following two statements:

1) The description via the \( \psi \) function of quantum mechanics is complete;
2) The real states of spatially separated objects are independent of each other.

The second statement goes by the name of "Einstein's locality postulate", which is clearly incompatible with the first, which asserts that quantum mechanics is a complete description! This incompatibility is the EPR Theorem. Thus there is a conflict between classical and quantum realisms, to resolve which calls for a precise experimental test. This test was formulated by John Bell [19] who made the concept of Einstein locality more precise by introducing "hidden variables" as a means of circumventing the counter-intuitiveness implied in the quantum description, and formulating suitable experimental tests in the form of Bell's inequalities for a suitable combination, say F, of the amplitudes for two spin-half particles moving in opposite directions. These combinations would differ according as the information on Einstein locality (no correlation for widely separated particles), or that for ‘quantum entanglement’ (no
matter how much their separation is), is incorporated. Then Bell's inequality reads as

\[ |F| \leq 2; \quad |F| \geq 2\sqrt{2} \]

for the two cases respectively. Actual experiment [20] upheld quantum mechanics, thus vindicating Bohr at least for now.

### 3.3 Bohr - Einstein Duality

The Bohr-Einstein controversy is a new form of Duality arising from the measurement problem. This is a strict consequence of the advent of Quantum theory which formally marked the demise of the so-called Cartesian Partition between the physique and the psyche, and brought about an intricate interaction between the two. The issue is one which deeply involves physics with philosophy, but it was lying more or less dormant for many decades. And now it seems to have suddenly sprung up to life during the last 3 decades, thanks to the i) growth of new experimental techniques (which have given a fresh lease of life to the experiments hitherto thought to be at the ‘gedanken’ level) on the one hand, and to the ii) development of quantum technologies of information processing and transferring on the other [21]. The movement has indeed grown up into a full-fledged industry, and shows no signs of abating, but its direction is not yet clear. It has no doubt generated a good deal of heat in the form of a glossary of technological jargon, but its concrete success on the physics front is so far highly questionable, since a resolution of the actual Bohr-Einstein debate is still far from over. Nevertheless, the physics-philosophy interaction that has thus been generated, formally opens up a bridge for taking physics to a higher plane of consciousness. The subject is not, since several stalwarts like Fritzof Capra [22], have addressed the issue, but the renewed interest generated by the measurement vis-a-vis locality problem gives it a further push. And this brings us to the last phase of this paper which offers a glimpse of what lies beyond.

### 4 Duality Partners Beyond Physics

So far we have discussed certain concrete facets of Duality during the historic growth of physics through the ages since Newton. In this development, the Cartesian Partition had remained in the background, without publicly appearing to influence the ‘contingent plane’ of empirical and analytic statements, a la Holton [4]. Newton himself had been aware of the duality between the physique and the psyche, but was inclined to project only the former, without active encouragement to the latter. His predecessor Kepler, on the other hand, had relied more heavily on the thematic concepts of the universe as a ‘mathematical harmony’, and a central theological order [4]. And Newton’s decisive influence on Western scientific thought had much to do with the uneasy balance between a materialistic pursuit of science and an idealistic devotion to philosophy, that had characterized the thematic development of physics till the early part of the twentieth century, when Einstein and Bohr came on the scene [23]. Einstein’s deep philosophy behind his unified view of space-time continuum on the one hand, and Bohr’s physical insight leading him to enunciate the Complementarity Principle (CP) as a paraphrase of the Uncertainty Principle on the other, marked such a radical departure from the Western attitude to science prevalent till then, that these had the effect of a “wind of change” on a relatively close and still atmosphere. In particular, the CP set the Western community of physicists on the formidable task of reorienting their attitudes as a result of intrusion of dialectics into their traditional modes of thinking. Interestingly enough, Bohr’s exposure of the same philosophy before the Japanese community met with little resistance to their traditional Eastern thought , as recounted by Yukawa to Rosenfeld [23].

What is the extra ingredient in Eastern thought with which Bohr’s CP philosophy found such a ready resonance, despite sounding so unorthodox to the Western school? This brings us to the contents of Table 2 which lists some dual partners on the interface between physics and philosophy that cannot be fathomed with the ‘standard’ methods of physical science. The items listed in this table need to be read from intuitive and commonsense considerations, with apologies to the orthodox methods of physical science (see below for further comments).

For any science in its formative stages, the traditional methods of limited hypothesis, checked against vigorous experimentation and vice versa, have usually proved much more effective than unfettered speculation of ideas with no comparable degree of experimentation to provide the balance. There comes nevertheless a stage in its development when this relatively mundane method fails to do adequate justice to the intellectual aspirations of the scientific thinker. A very similar stage has been reached in
modern physics where the unification of opposite concepts represents precisely such an aspiration where
the experimental support often lags so far behind the theoretical ideas, that faith in the latter must,
in the interim, be sustained by considerations of a thematic nature, well before eventual experimental
confirmation, if at all. Such opposite concepts abound at the sub-atomic level where particles are both
continuous and discontinuous; and force and matter are but different aspects of the same phenomena.
In all these examples it turns out that the ” framework of opposite concepts, derived from our everyday
experience, is too narrow for the world of subatomic particles ” (Capra, ref [22]).

Some of these situations have already been illustrated under the unification (as well as measurement
incompatibility ?) aspects of Duality in the foregoing. In each case, the unification occurs on a higher
plane; e.g., space and time become a single entity only in a 4-dimensional continuum; wave and particle
manifestations of an electron / photon get unified only at the quantum level; matter and anti-matter
require a further synthesis of relativity and quantum theory for a mathematically self-consistent description ; and so on. Fritjof Capra in his remarkable book, Tao of Physics [22], has documented a large class
of such examples (through extensive quotations from appropriate religious, philosophical and scientific
authorities), in his exploration of parallels between Western physics and Eastern mysticism, and revealed
a profound harmony between the two. In particular, he portrays a simple picture, emanating from the
Chinese symbolism of the archetypal poles Yin and Yang- two extremes that are constantly engaged in
a dynamic interplay which brings about their unity (Tao) on a higher plane. This picture has a simple
physical analog in the example of a circular motion and its linear projection [22], which is illustrated in
Fig. 2. Note that the continuous oscillation between the two opposite points (Yin - Yang) is a character-
istic only of the linear projection, while the more complete two - dimensional circular motion shows
no such fluctuation.

At this stage, it should be appropriate to cite an example given by the Man in whose honour this
article has been designed. And this is from the Jain Philosophy of Saitavada which shows a remarkable
parallel in wave-particle duality of quantum mechanics, via its fourth mode of realization of reality,
namely Avayakta (inexpressibility), as described by Kothari in one of his last publications [24].

4.1 Consciousness Dominated Physics ?

Since consciousness is very much a part of the physique - psyche duality, one might wonder if the roles
of these two items could be interchanged, and a quantum theory based on the dominance of the psyche
(consciousness), instead of the more conventional theory dominated by the physique (matter), be pursued
seriously. Actually one such approach has been offered in a recent book [25] by Amit Goswami, a physicists-
turned- philosopher, but it is still too premature to let such ideas, howsoever appealing, compete on equal
terms with conventional quantum mechanics.
5 Conclusion

Coming back to our Duality theme, we end this narrative with the observation that mystics through their meditation transcend the realm of intellectual concepts and in so doing, become aware of the polar relationship of all opposites. Physicists grope for a glimpse of the same through their language of mathematics. Western philosophers have been keenly aware of this duality (see, e.g., Emerson’s thesis on the hidden law of compensation [1]). And today, theoretical physicists are increasingly feeling its impact as they probe deeper into the mysteries of the sub-atomic world down to $10^{-17}$ cm, but theoretically all the way to Planck’s length, having received its first taste in Bohr’s CP, supported experimentally by wave-particle duality. There is no going back on this journey, irrespective of the source, be it modern physics or mysticism, of its inspiration.

REFERENCES

[1] A.N. Mitra, *Duality in Physical Sciences and Beyond*, Pramana-J. Phys. 27, 73-87, (1986).
[2] H. Goldstein, *Classical Mechanics*, Addison-Wesley, Reading, MA, USA, (1950).
[3] P.A. M. Dirac, in *A Lifetime of Physics*, IAEA, Vienna, (1968).
[4] G. Holton, *Thematic Origins of Scientific Thought*, Harvard U Press, (1973).
[5] F.J. Dyson, Phys. Rev. 75, 486, 1736 (1949).
[6] R.P. Feynman and A.R. Hibbs, *Quantum Mechanics and Path Integrals*, McGraw Hill, N.Y., (1965).
[7] J. Schwinger, *Particles, Sources and Fields*, Addison Wesley, Reading MA, (1973).
[8] R. Dolen et al., Phys. Rev. 166, 1768 (1968); A.A. Logunov et al., Phys. Lett. B24, 181 (1967).
[9] G. Veneziano, Nuovo Cimento 57, 190 (1968)
[10] Y. Nambu, in *Symmetries and Quark Models*, (ed) R. Chand, Gordon and Breach, N.Y. (1970).
[11] F.J. Dyson, *Lecture Notes on Advanced Quantum Mechanics*, Cornell Univ, (1952).
[12] J. Wess and B. Zumino, Nucl.Phys. B70, 109, (1974)
[13] N. Bohr and L. Rosenfeld, in *Developments in the Theory of the Electron*, (ed) A. Pais, Princeton U Press, (1948).
[14] J. von Neumann, *Mathematical Foundations of Quantum Mechanics*, Princeton U Press (1955).
[15] See, e.g., H.P. Stapp, Am J. Phys. 40, 1098 (1972).

[16] Einstein, Podolsky and Rosen, Phys. Rev. 47, 777 (1935).

[17] V. Singh, quant-ph/0412148.

[18] A.N. Mitra, quant-ph/0510223.

[19] J. S. Bell, Physics 1, 195 (1964).

[20] A. Aspect et al, Phys. Rev. Lett. 49, 91, 1804 (1982).

[21] D. Home, Perspectives in Quantum vs Classical Reality, 2002 (unpublished).

[22] F. Capra, The Tao of Physics, Fontana, London (1976).

[23] L. Rosenfeld, Phys. Today 16, 47, (1963).

[24] D.S. Kothari, Complementarity and Syadavada in Niels Bohr-A Profile, (ed) A.N. Mitra et al, Ind Natl. Sci. Acad, New Delhi, 1985.

[25] Amit Goswami, Physics of the Soul, Hampton Roads Pub Co, Charlotsville VA, 2001.