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The concept of relation and the explanation of the phenomenon of *Entanglement*

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Abstract

We investigate from a philosophical point of view the *concept of relation* that is used to explain the physical phenomenon of *Entanglement*. If the concept of relation is understood in the ordinary sense of the mono-dyadic construct, which requires a middle term between the two extremes, it is *aporetic* and, thus, incapable of explaining the phenomenon. To the contrary, we propose to think the relation as the *act of self-referring* of related terms, which is *unique* and *identical* for both terms. In the unity of this act, the duality of terms disappears, so that the *authentic unity* is obtained. Moving from this concept of unity, the phenomenon of *Entanglement* becomes intelligible, since the *two particles emerge as the two abstract sections of a unique reality*.

I. Introduction

Quantum physics has investigated the problem of *Entanglement* from a physical point of view, and philosophers of science from an epistemological point of view. However, the phenomenon of *Entanglement* cannot be fully understood unless the *concept of relation*, which is intrinsic to it, is directly thematised. This concept, indeed, plays a central role in it, as noticed by Esfeld:

> "Being entangled with" is a property that is predicated of at least two quantum systems; it is thus a relational property. By admitting entanglement, we are not committed to taking a particular stance on the

> notorious measurement problem in quantum theory: Even if one maintains that measurement leads to a dissolution of entanglement so that, as a result of measurement, quantum systems really have definite numerical values of some state-dependent properties, entanglement has to be there in the first place before it makes sense to consider the question whether or not there are processes that dissolve entanglement.[1]

Starting with this quotation from Esfeld, the aim of this article is to reflect on the underlying fundamental concept: the *concept of relation*. Indeed, we think that it is this concept that must be carefully investigated, to provide a conceptual explanation of the *holism* that emerges from *quantum physics* and from the phenomenon of *Entanglement* that is inherent in it and constitutes an aspect of particular interest.

The centrality of the concept of relation also emerges from another article by Esfeld. In it, the author distinguishes his position from both that of substance metaphysicians like Lowe, Simons, and Heil – who maintain that there are objects with intrinsic properties, and that relations are supervenient to them – and philosophers of science, such as Ladyman – who instead maintain that relations, understood as structures, are fundamental, in the sense that there are no objects outside these relational structures. In fact, Esfeld claims that

> As far as the ontology is concerned, the paper argues that the challenge to a metaphysics that relies on a commitment to substances and intrinsic properties stems from the relations of quantum entanglement, with Bell's theorem ruling out the possibility of reducing these relations to something that is not a fundamental, dynamical relation. However, these relations are instantiated by objects (substances) that are individuated independently of these relations.[2]

This sentence is very interesting because, to highlight that objects are instantiated by relations but individuated independently from them, it refers to the concept of *Entanglement*, without defining, however, the concept of relation on which the claim is based.

Recently, new studies have been devoted to the phenomenon of *Entanglement*.[3] The phenomenon has also been studied in relation to its multiple applications and uses.

We are interested in the phenomenon of *Entanglement* essentially from a philosophical viewpoint, not an epistemological but a theoretical one.

1. Esfeld (2003: 14).
2. Esfeld (2017: 218–219).
3. Among the recent studies in philosophy of science, there are Laudisa (2001), Cordovil (2015), Dorato (2015), Dorato (2017), de Ronde and Massri (2021) Calosi and Morganti (2021). An updated and reasoned account of the philosophical relevance of quantum physics in general and *entanglement*, in particular, can be found in the two entries of the *Stanford Encyclopedia of Philosophy* by Bub (2020) and Myrvold (2018).

Now, if we consider the philosophical literature on quantum theory in general, and the phenomenon of *Entanglement*, in particular, we can notice that it focuses mainly on the practical–operational aspects, neglecting the theme of the *relation between theory and reality*. When this relation is investigated, one asks whether the theory must be interpreted in *realistic terms* or in terms of *mathematical formalism*.

In this study, we start from a brief description of the phenomenon of Entanglement, and then present some fundamental criticisms of it, expressed in the well-known "EPR paradox", an acronym of the three physicists who criticised this phenomenon, i.e., Albert Einstein, Boris Podolsky, and Nathan Rosen. They maintain that the only way to explain this phenomenon without recourse to a superluminal communication or interaction (i.e., to a speed greater than "*c*", which is the speed of light) between two entangled particles consists in introducing, as a hypothesis, some specific "elements of reality" that are immediately evident.

"Nonlocality", i.e., the possibility of "action at a distance", represents the *first theme* that we intend to investigate. Indeed, in our *ordinary* reality, systems *do not interact* with each other when they are placed at a distance that does not justify their interaction. We will try to provide an explanation for such interactions occurring among ultramicroscopic particles.

The *second theme* that we analyse is represented by the concept of "reality". Ordinarily, the principle of non-contradiction is applied to reality, so that an entity *aut* is "A" *aut* is "non-A", but it cannot be both at the same time and in the same respect. On the contrary, the reality that is described by quantum physics is characterised by "states superposition", i.e., a reality which could be defined as contradictory, since we would have both "A" and "non-A" at the same time.

The third theme, summarising to some extent the two preceding ones, is "non-separability". "*Nonlocality*" is expressed not only as "*non-separability*" of states that represent a unique ultramicroscopic entity, but also of two *entangled* particles. Now, we think that the concept of non-separability needs to be carefully analysed, since it cannot be understood according to the interpretation that might initially suggest itself.

We will try to prove that in order to understand the concept of "non-separability", one needs to adequately understand the *concept of relation*. If this is understood as a *mono-dyadic construct*, then the phenomenon of *Entanglement* cannot be explained, and its critiques are well founded. However, if the ordinary concept of "relation" is overcome, then the phenomenon can be understood in its full meaning, and the *unity* is revealed as the ground of reality: unity represents not only the ground of the ultramicroscopic reality, but also of ordinary reality, because the

"elements" that constitute the latter manifest only *apparently* an independent identity.

II. The EPR Paradox

In May 1935, the prestigious *Physical Review* published an article called: "Can quantum-mechanical description of physical reality be considered complete?"[4] In this article, the argument known as the EPR Paradox was first presented.

The aim of Einstein and his colleagues was to prove that quantum mechanics presents some paradoxical aspects that show its incompleteness. The article starts from the assumption that any physical system can be defined as a set of three hypotheses: *Realism*, *Arrow of Time* and *Locality*.

Realism presupposes the existence of a reality that is independent from the observer, from his observations, and the possibility of relying on some criteria to identify fields in which this reality is present. The *Arrow of Time* presupposes that future events cannot modify the past. The Arrow of Time also implies that cause and effect cannot occur at the same time. Indeed, two "contemporaneous" events would violate a fundamental principle of Relativity, that is that nothing, (not even information) can travel faster than light. Finally, *Locality* (or Local Realism) is the idea according to which two entities separated by a large distance exist independently of each other, so that an action affecting one of the two does not affect the objective properties of the other.

Regarding the latter aspect of their argument, EPR believe that, for us, the existence of a "local reality" is central; that is, they believe in a *space limited action* of the "objects" in the world.

More specifically, EPR's argument refers to the positional measures and the momentum of two particles that are conveniently predisposed in a conjunct state which, thanks to a wave function, is specified mathematically. After they have been disposed conjunctly, the two particles are moved away and, no matter how large their separation is, the authors show that quantum theory never allows us to consider the results of realised measurements independently, and that there must always be some sort of *connection* or *correlation*, which, however, cannot be explained within the context of non-quantum physics.

According to EPR, the only possible explanation of the phenomenon of *Entanglement* that does not resort to a superluminal communication or

4. Einstein *et al.* (1935).

interaction between two particles, consists in introducing some "elements of reality" which, being incompatible with quantum physics, would convert the latter into an incomplete theory.

In 1948, Einstein again analyses the theme of Local Realism in these explicit terms:

> The following idea characterises the relative independence of objects far apart in space (A and B): external influence on A has no direct influence on B; this is known as the 'principle of contiguity', which is used consistently only in the field theory. If this axiom were to be completely abolished, the idea of the existence of (quasi-)enclosed systems, and thereby the postulation of laws which can be checked empirically in the accepted sense, would become impossible.[5]

Thus, according to Einstein and his colleagues, Quantum Mechanics' violation of Local Realism cannot be maintained. Einstein knows that nothing can exceed the speed of light: how can a signal be transmitted instantaneously to a particle which is very distant and potentially located in a different part of the universe? Quantum mechanics which allows for *action at a distance* must thus be incorrect or at least incomplete. To describe this action at a distance (or nonlocal action), Schrödinger would subsequently use the term *Entanglement*.

III. Nonlocality and quantum mechanics

Nonlocality (i.e., the possibility of "action at a distance") is one of the specific phenomena that characterise quantum mechanics. In *ordinary* reality, interactions among systems at a distance never occur directly or in real time.

For example, a pandemic disease originating in Asia does not immediately spread in Europe as well. To reach the latter, it takes some time; indeed, several weeks are needed for the infected individuals to spread the virus, moving from one place of the world to the other. This is an example of *localism*, which does not apply to the world of quantum physics, where actions between different places in space occur frequently.

To get a clear idea of quantum *nonlocality*, imagine that we have in front of us two boxes, each containing a glove belonging to a pair. It is "obvious", even before inspecting the boxes, that they will each contain a glove with a well-defined "direction": the box on the right, for example, will contain the right-hand glove, and the box on the left, the left-hand glove, or vice versa.

5. Einstein (1971: 171).

Now, if instead of resorting to normal gloves, we used "quantum gloves", we would realise that the direction of gloves, in the corresponding boxes, would be defined only when looking inside one of the two boxes. The act of looking inside one of them confers *reality* on the pair of gloves; it also confers, at a distance (i.e., *nonlocally*) and instantaneously, a direction to the glove which is *not the subject* (at that moment) *of observation*.

According to the quantum paradigm, before the *observation*, before the observer's decision to look inside one of the boxes, gloves *live* in a superposition of states, i.e., *entangled*; a state according to which gloves are "mixed" in a *unique entity*: a *left–right* glove. In the context of the orthodox interpretation of quantum theory, the objective characteristics of any micro-entity, or pair of micro-entities, are defined in the very moment when observation takes place: it is only the act of observing that *solves* the superposed state characteristic of matter.

We need to clarify an aspect that could at first seem purely semantic, and which concerns the terms used to define *action at a distance*. Einstein, Schrödinger and other "classical" physicists use the term "nonlocality" or "*Entanglement*"; to define systems that are subject to actions at a distance, orthodox quantum physicists instead use the term "non-separability".

Indeed, by literally applying the mathematical formalism of quantum mechanics to our two quantum gloves, we should resort to a *unique* wave function and consider our two gloves, even if separated, as a *unique entity*: a *left–right* glove, indeed. Thus, nonlocality becomes non-separability, since for quantum mechanics, even spatially distant gloves must be considered as a *unique entity* (a "non-separable entity").

The well-known quantum physicists Anton Zeilinger, in his book *Einstein's veil*, presents this situation very clearly. Indeed, he writes: "First of all, these two particles constitute an inseparable entity and, as long as all measurements of the couple of particles are not concluded, we cannot have an idea of the behaviour of only one of them".[6] And then he adds: "Bohr proposed that the two entangled particles, independently of their distance, would continue to constitute a *unity*, *system*. The measurement of one of the two particles modifies the state of the other; that is, *the two particles have no independent existence*".[7]

6. Zeilinger (2003: 121, our translations).
7. Zeilinger (2003: 121–122, italics added).

IV. Bell's theorem and inequality and Aspect's experiments

In 1964, almost 30 years after EPR, the Irish physicists John Bell (1964) proved, in a mathematically rigorous way, that it is experimentally possible to settle the dispute that had opposed EPR – and "local" physicists in general – to quantum physicists. "Bell's inequality has been defined by the Nobel Prize recipient Brian Josephson as 'the most important breakthrough in recent physics'".[8]

Bell derives an inequality between measurable quantities that should, in princple, be satisfied by all theories that include in their formulation elements of local reality and that, instead, are not satisfied by the theoretic predictions of quantum mechanics.

In a few, yet remarkable pages, Bell laid the groundwork for the possibility of what, in the philosophy of science, is defined as the *crucial experiment*.

In this case, it represents a new experimental situation, never conceived or tested before, according to which the theoretical prediction of quantum mechanics differs from what any theory does in assuming the existence of elements of local reality. In other words, Bell's inequality does not compare quantum mechanics with a specific alternative theory, but with *all theories that take into account "local" elements of reality* (as, e.g., the positions that emerged from the EPR paradox).

In short, Bell proves that, if the hypothesis of EPR and localists is true, then thanks to a particular experiment an algebraic inequality between two physical magnitudes must be satisfied; this mathematical proof is known as "Bell's inequality", which in turn starts from the more general "Bell's theorem", which maintains that quantum mechanics is incompatible with local realism.

One can argue that the contribution of Bell's inequality to science is limited only to the proof that there exists a specific way to rigorously define Localism (Localism violated in quantum mechanics): wherein consists the ground-breaking novelty of Bell's contribution, then? Where, to use Josephson's words, does the importance of Bell's contribution to science lie?

The answer can be found in the *universality* of his inequality. Indeed, Bell's inequality is independent from quantum mechanics; through an elegant mathematical construction, it presents (with its violation) a *nonlocal a priori world*.

The universality and importance of Bell's inequality lies in the fact that it can be applied to any sector of the world, from the microworld

8. Ghirardi (2007: 194).

(photons, electrons, etc.) to tennis balls, from groups of people to pairs of galaxies.

As the physicist and philosopher David Z. Albert says in his book, *Quantum Mechanics and Experience*:

> What Bell has given us is a proof that there is as a matter of fact a genuine nonlocality in the actual workings of nature, however we attempt to describe it, period. That nonlocality is, to begin with, a feature of quantum mechanics itself, and it turns out (via Bell's theorem) that it is necessarily also a feature of every possible manner of calculating (without or with superpositions) which produces the same statistical predictions as quantum mechanics does; and those predictions are now experimentally known to be correct.[9]

More starkly, but still along the same line of thought, the physicist James Cushing says:

> Bell never wrote down a single, local deterministic theory. Rather, he proved, without ever having to consider any dynamical details, that no such theory can in principle exist. The entire class was killed at a stroke – a classic "no-go" theorem. [Further,] Bell's theorem really depends in no way upon quantum mechanics. It refutes a whole category of (essentially) classical theories without ever mentioning quantum mechanics. Abner Shimony has appropriately given the name "experimental metaphysics" to this type of definitive empirical resolution of what appears to be a metaphysical question.[10]

The contraposition between the representatives of quantum mechanics, on the one hand, and those who supported localism (Einstein et al), on the other hand, was settled in 1982, when Alain Aspect, in collaboration with two researchers, J. Dalibard and G. Roger, from the Institute of Optics of the University of Paris-Orsay, conducted a series of highly advanced experiments,[11] which unequivocally proved the soundness of the theses maintained by quantum physicists.

The experiments conducted by Aspect proved that, even at a spatial distance, the act of measuring the polarisation of a photon of a correlated pair led to an instantaneous fall of the wave function of the "twin" photon (even at a distance of thirteen meters, which is an enormous distance for a subnuclear particle). In other words, nature followed the predictions of quantum mechanics, violating Bell's inequality.

Even if unexpected, this is what happens when experiments are conducted on pairs of correlated particles (or that have interacted in the past), and this applies not only to photons, but also to massive particles.

9. Albert (1992: 70).
10. Quoted in Ghirardi (2007: 226).
11. See Aspect *et al.* (1982).

Now, our aim is precisely to answer the question of how *entangled* particles can be *distant*, even if they are not truly *distinct*.

V. The philosophical interpretation: the concept of "relation"

There are many themes here that need to be investigated. They concern, first of all, the concept of reality, understood as "superposition of states". Secondly, the notion of "nonlocality", as exemplified by the phenomenon of "Entanglement".

In order to provide a conceptual explanation of the phenomenon of *Entanglement* that would also clarify the sense of *nonlocality* and *states superposition*, we start from the concept of "relation" as it is ordinarily understood.

We notice that the *concept of relation*, according to the common interpretation, plays a fundamental role, for it combines multiplicity – even in its minimal form of duality – with unity, which is represented by the *nexus,* which is both unique and common to the terms in question.

Ordinarily, when we refer to the concept of relation, we conceive of a construct formed by two extremes (A and B) and a nexus (r) that binds them. For this reason, the expression "mono-dyadic construct" is used, and the construct is expressed in this formula: r (A, B).

On the basis of this construct, nonlocality and the phenomenon of *Entanglement* are questioned by EPR. They notice, indeed, that if a *middle term* between the two entities is not given, then there is no relation between them. Without a binding nexus, they are independent from each other, so that no interaction is justified.

Our counterargument starts from the analysis of the *limit* of the ordinary concept of relation. Then, we will discuss the concept of "independence" of determinate identities, i.e., of entities, whatever their magnitude.

We want to stress that the concept of relation plays a very important role within the empirical–formal universe, since it is only by virtue of this construct that an ordered system is set up in which chaos is prevented, since every entity exhibits its own identity, different from the identity of every other entity, even though related to it.

However, this ordinary understanding of the concept of relation is problematic. Indeed, if a relation is thought to obtain between A and B, then it appears as a new term: the *middle term*. On the one hand, the latter joins A to B; on the other, it separates A from B.

If this *quid medium* is indicated by the letter C, then this gives rise to two new relations, one occurring between A and C, and one occurring

between C and B. With this very important consequence: from these two new relations, we can obtain two new middle terms, and so on to infinity.

Now, the inconclusiveness of this *regressus in indefinitum* is highlighted by Plato in his *Parmenides*, when Parmenides discusses the relation between ideal models and things.[12] Aristotle, in his *Metaphysics*, refers to the argument called "the third man", to indicate the aporetic character of the Platonic concept of "participation",[13] when – we would like to add – it is reduced to the ordinary concept of relation.

In addition to these criticisms introduced by Plato, we think that it is possible to add some further considerations. Indeed, a relation assumes the identity of each term in the relation (A and B) with itself. This occurs according to the way in which identity is normally understood, which implies that both A and B express *an identity of each term with itself, and for this reason each term is different from the other.*

A and B are two identities, i.e., two entities showing their autonomy and self-sufficiency, so that we can refer to one of the two without resorting to the other. If this were not so, i.e., if any such identity could not be considered as autonomous, it could not even be codified, and we could not say "A", nor could we say "B". If one says "A", then with this letter one indicates an identity that exists independently from anything else, and the same applies to "B".

However, starting from this, we face two problems: one is due to the fact that the relation is grounded on an identity understood in this way; the other, the problem represented by the concept of identity, is that identity is understood in this way.

To tackle the first problem, we can consider that the concept of relation tries to reconcile two mutually exclusive demands: on the one hand, it assumes the identity of the related terms; on the other hand, it requires that the identity of one of these be *not closed*, i.e., autonomous and self-sufficient, but be *open* to the identity of the other term, so as to justify their bond. But it is precisely the bond that cannot be reconciled with the autonomy of the identity of terms. Indeed, if A is A because it is autonomous, then when it enters into a relation with B, it loses its autonomy and, thus, ceases to be A. If it did not disappear as A, no relation would obtain.

Duns Scotus clarified this point when he said that if the union of A and B expresses no more than A and B taken absolutely, i.e., as autonomous and self-sufficient, then the compound set of A and B would not differ in anything from A and B taken separately, so that it would not be

12. Plato, *Parmenides*, 130e–132b in Plato (1996: 28–30).
13. Aristotle, *Metaphysica*, I, 9, 990b 1–18, in Aristotle (2016: 20–21).

a compound set at all: in other words, we would not have a relation at all.[14]

At this initial level of investigation, we can make a preliminary observation on the phenomenon of *Entanglement*. If one assumes that particles are originally entangled, that is, they arise in a reciprocal relation, then we would not understand how a transformation may occur in one of them without the other being affected.

Applying Duns Scotus's reasoning, if the second were not affected by the change affecting the first particle, then no relation would exist among them. Thus, the question now is: does the relation continue to exist when particles are very far apart?

The point is this: if the relation is understood as a nexus between the terms, then the nexus disappears when the terms are placed at a sidereal distance. But it is not necessary to draw this conclusion: when defining a relation, indeed, we have not specified the distance between the terms the nexus must cover. It is only the connotation pertaining to physics as science that requires the nexus to be responsible for its length. Thus, this is a *physical, not a conceptual question*. Conceptually, the length of the nexus is not relevant, but only its existence.

Moreover, we can notice that relation, as Duns Scotus thought, is understood not as a construct but as "reciprocal influence" between terms, or as *respectus* (σχέσις) of one term with respect to the other, i.e., as their *reciprocal disposition*. For this reason, we have said that one should wonder whether the change in one particle *would not be immediately followed* by a change in the other, since the latter is intrinsically bound to the former. If this change did not occur, it would mean that particles are independent, and the initial hypothesis, i.e., that they are originally *entangled*, would be dropped.

Critics maintain that particles are in a relation if, and only if, the distance between them does not exceed a certain limit. However, the experiment proves that this is not the case: particles continue to be entangled even if at a sidereal distance. We have tried to provide a conceptual explanation of why this must be so. Why should one deny the experiment and the conceptual explanation that supports it, to maintain a concept of relation that is only "physical"?

We think that even a physics investigation would benefit from an analysis of such fundamental concepts as that of relation. For example, is the mathematical concept of *function* excluded from physics? Still, in this concept, the correlation among variables is independent from the middle term, because the concept of relation emerging from the concept of

14. Duns Scotus, *Opus Oxoniense*, ii, d. 1, q. 4, n. 5, in Duns Scotus (1950).

function is that of relation as reciprocal influence, i.e., as *respectus*, not that of relation as a construct.

According to our interpretation, the question should be overturned. We should not ask how it is possible that a change in a particle immediately effects a change in another particle, even if placed at a sidereal distance. Instead, we should ask how it could be possible that, given two intrinsically entangled particles, *a change in one could not produce a change in the other*.

How this happens, amounts to a different problem and cannot do away with the *necessity* that this occurs. Unless, of course, one maintains that, if two particles are distanced enough, they cease to be in connection. In this case, however, one would question the assumption that they are two intrinsically connected particles, whatever their distance between them.

Concerning the "how", it seems to us that "Bell's Theorem and inequality" have clearly settled on the validity of all nonlocal theses, given that, as we said above, this theory can be applied to any field, from the microworld (photons, electrons, etc.) to tennis balls, and from groups of people to groups of galaxies.

In the next section, our aim is precisely to provide a precise *conceptual* clarification of the meaning of this universal validity of Bell's arguments.

VI. Reality and states superposition

To synthetise this point, we could say: it is one thing to understand *the means through which* the action of one particle (entity) on another is produced, so that the latter is modified, and this is primarily an issue physics is interested in; it is another *to understand the necessity and the meaning* of the influence that produces change - this is primarily a philosophical problem, and one that should also be of interest to physicists.

To understand how this happens, it is essential to understand the *meaning of the difference* between A and B, which is the ground of the *distance* between them. Indeed, if one could prove that, at the level of the ultimate ground of experience, there is no difference, then distance – which is an expression of difference – would belong to a more surface level of reality. In other words, if one could prove that there are not two entities, A and B, but a unique reality, which is the *unity in which A and B are sublated* (i.e., disappear in their individual identity), then intervening on A would be the same as intervening on B, and vice versa. Our intention is precisely to provide this proof, and to this aim, we start from the concept of "objective reality".

The theme of *objective reality*, i.e., reality *absolutely independent* of the subject, is of interest to science in general, and to physics, in particular. The need to grasp this reality, in its ultimate ground, culminates in quantum physics in the concept of "states superposition". Any elementary particle, not only photons, *is in itself a unity*, and this provides a first significant insight into the ultimate ground of reality.

It is true that the concept of unity used in quantum physics is understood as a *synthesis* of two terms. For this reason, we should not use the concept of unity here, but instead that of *unification*, which is still a relation reconciling two irreconcilable states, so that it represents a *contradiction*.

We would like to highlight the following: it is not only nonsensical to understand objective reality as a contradiction, but a genuine contradiction is also to assume as objective reality (i.e., as absolutely independent from the subject) that which is instead the result of the process of *reunification* of two observations of that same reality, obtained by an activity of the subject. States superposition, understood as a unification of wave and particle, is not objective reality, but a *connotation of objective reality starting from its detection* (observation), which is, by its very nature, subjective.

Thus, the contradictory aspect of states superposition is the projection of the contradiction of the claim of grasping reality in itself (*kata physin*, *in se*) onto the object of knowledge, as if grasping the latter would not transform it *eo ipso* into a reality for us (*pros hemas*, *quoad nos*).[15] Similarly for assuming as *in se* the *outcome of the reunification* of the two states detected by the subject.

More generally, we could say that *truly* objective reality cannot enter into a relation with that which is other from it, nor can it be structured by a relation. If it is structured by a relation, hence also as a superposition of states, it is only *falsely* objective, so that the *authentically objective* reality must be found elsewhere. We think that it can only be found in the *unity* that, being absolutely itself, cannot but escape any relation, be it extrinsic or intrinsic. In this way, the concept of unity, as a last ground, can find its *legitimation*.

We must observe that the *objective factor* is necessarily required for interpreting the data of experience. Without it, and if everything relied on the *subjective factor* only, we would end up in the perspective of absolute idealism, which considers data as the subject's "creation". But this cannot be so. The objective factor is essential to explaining the *relative independence* of experience with respect to the subject. We use the term

15. The theme of *objectivity* and metaphysical realism is further developed in Stella and Ianulardo (2018).

"relative independence" because experience depends on the subject, but not absolutely. Moreover, experience is independent from the subject, but this independence is not absolute.

On the contrary, the *objective factor* cannot but count as *absolutely independent* from the subject, so that it cannot in any way be *determined* by the subject. Thus, the objective factor must emerge beyond the universe of determined beings, i.e., the empirical–formal universe.

It is only the *Parmenidean being* that represents this absolute independence and counts as the true *unity* in which any difference disappears, since any difference from being must be "non-being".

To better understand the sense in which we claim that, at the level of the ground, the difference is *sublated* in the *unity*, we must now return to the concept of "relation" and explain how it can be understood as essentially a unity.

VII. The intrinsic value of relation

Beyond its above-mentioned forms, the concept of relation can be understood in another way, which we will present through the following argument. To characterise this concept, we first go back to its ordinary interpretation, and to the solution that has been provided to the problem of reconciling both the independence and dependence of terms.

In order to solve this problem, one could advance the hypothesis that A is A before entering into a relation with B, and becomes A_1 after having entered into this relation (and the same applies to B, which becomes B_1). In this case, however, we would obtain two new relations: one between A and A_1, and another between B and B_1. In this way, the difficulty we found previously would occur again, because both A and B should count as two identities, which, despite being autonomous, could not exist without being related to each other.

Thus, the relation needs the two terms – as if they were two distinct and autonomous entities (A is not B), but, at the same time and contradictorily, as if one of the two terms were grounded in the other (A exists because B exists; A cannot stay without B). This amounts to saying that the mono-dyadic construct reconciles the independence of the terms with their reciprocal dependence, and so *reconciles that which is, in itself, irreconcilable*.

The ordinary *status* of the relation can also be put in this way: the terms must differ from each other, but the condition of their differing is precisely the nexus that binds them, since the difference is itself a relation. Moreover, the terms must be in a relation, but the condition of

their relating to each other is precisely their existence as distinct terms, i.e., their being irreducible to each other, since the relation can represent their middle term only if they remain two.

Synthetically, despite seeming paradoxical, *relation binds because it differentiates*, and it *differentiates because it binds*. This is the problematic aspect of its *status,* and it connotates the relation as a construct without there being a solution to it. Thus, keeping relation as a construct for trying to reconcile the independence and dependence of terms means, not only keeping the *conciliation of irreconcilable terms*, but also thinking of it as *extrinsic with regard to identity*.

It is placed *between* the two terms because this is the only way to save the empirical–formal universe, that is, the universe grounded in the identity of the "given" (of the "thing" that is given in experience), which is assumed to be *autonomous* and *self-sufficient*. But then we should ask the following question: can identity be truly considered as "autonomous" and "self-sufficient"? Only when we grasp the *authentic meaning of identity* can we solve the problem of whether the relation must be understood as *extrinsic* or *intrinsic* to identity.

To understand the concept of identity, we can start from the way in which it is ordinarily understood. The principle of identity maintains that any object is identical with itself and, for this reason, different from any other object.

However, we should notice that if, when speaking of identity, we mean a *determinate identity*, then we cannot forget that what determines it, i.e., makes it finite, is precisely the *limit*. The limit is characterised by two faces: one looking at the limited, and the other looking at that which limits. This explain our previous claim that a determinate identity is constituted thanks to its differing, i.e., its contraposing to another identity: A is A because it is non-A. This yields the following conclusion: the determinate identity cannot be considered as autonomous and self-sufficient.

It is only the identity of the absolute that does not require a relation, and for this reason the absolute is defined as such: *ab-solutum*, indeed, indicates "that which is free from bonds, relations". But it is precisely for this reason that the absolute cannot be determined.

On the contrary, when speaking of a determinate identity, the *opposing relation* to the difference becomes essential. With this important consequence: if relation is essential to the constitution of identity, then we must question the sensory representation that places non-A outside A. Representation, indeed, may lead us to think that *some sort of independence* may continue to exist, since A and non-A occupy different places, even in the sentence.

On the contrary, maintaining that non-A is essential to the constitution of A (and vice versa) means that *difference is recognised as intrinsic and constitutive of identity,* and this requires going beyond the empirical–formal universe.

Relation – and this is the crucial point – cannot be thought of as taking place between A and B, but as *immanent* to A and B, according to what Hegel says in *The Science of Logic*, where he distinguishes *external relation* (*äußerliche Beziehung*)[16] from *internal relation* (*immanente Synthesis*).[17] The former coincides with the mono-dyadic construct and considers the identity of terms as autonomous from the difference; the latter instead rests on the principle Hegel takes over from Spinoza, viz., that *omnis determinatio est negatio*: any determination is negation and thus *referring itself to that which differs from itself.*

When we reach the conclusion that A and B are two identities constituted only thanks to *their referring to each other*, then this referring cannot be thought of as subsequent to the constitution of A and B, but *it must coincide with the being of both*: A is in relation to B, and vice versa, because A cannot remain without B, so that B *enters into the intrinsic constitution of A,* and the relation is revealed as an intrinsic relation (*immanente Synthesis*).

To grasp the *constitutive value of relation,* one must rethink the concept of identity: *any identity, in itself, refers to that which is other than itself*, as we saw when we discussed the role played by the limit in positing a determinate identity. And if any determinate identity *is its own self-referring to the difference*, then relation cannot be considered as a hypostasis, i.e., as a *middle term*, but must be understood as the self-referring of one term to the other: any term is in itself the *act of self-referring* to the other-than-itself. Here, we use the term "act" instead of "activity", because the latter would reproduce the duality between the subject and object of the action, whereas the *act* is intrinsically unitary.

Before further investigating this *new concept of relation*, i.e., relation as the *act of self-referring*, we want to recall that even at the macroscopic level there are no *effectively* independent entities. This is not new, since many philosophers have already claimed it and Bell's theorem clearly states it.

However, the implication of this intrinsic nexus is not always noticed, because objects have been maintained in their identity – as if the latter could be assumed *independently* from its referring to the difference, i.e., as if A could do without its reference to non-A.

16. Hegel (2010: 32).
17. Hegel (2010: 72).

Having clarified the meaning of identity and laid the foundation for the new concept of relation, the argument we develop next aims to show that, if two entities are considered as "inseparable", if they are both micro and macro, they in effect constitute a *unique reality*, of which the two entities count as two *abstract* sections.

As we have seen, Zeilinger has spoken of two particles that "constitute an inseparable entity", and he has noticed that "the two entangled particles, independently of their distance, would continue to constitute a unity or system". Now we must reflect precisely on this *coincidence between inseparability and unity*, starting from the concept of relation as "act".

VIII. Relation as "act"

Any determinate identity is thus resolved in the *act* that refers it to that which differs from it. This *act* is the *same* for any determination, and thus it is unique. In this *same* and *unique act*, the multiplicity of determination is neutralised with respect to the difference that characterises each of them, so that all differences are resolved in the *unity of the act* that constitutes their authentic ground.

We can reach the same conclusion using a different argument. If, as we noticed earlier, we acknowledge that any determination exists only to the extent that is referred to its difference, in the sense that A exists only to the extent that is referred to non-A, then we can grasp the *co-essentiality* that exists between A and non-A.

Some philosophers have acknowledged this *co-essentiality*[18] – so that one could speak of co-essential determinations, since this is intended to preserve the multiplicity – even if they acknowledge that each determination is *insufficient to itself* (i.e., cannot explain itself without referring to another determination). Instead, we think that by speaking of "co-essential" determinations, we lose their coessentiality.

What does this coessentiality imply? It implies that if non-A is coessential to the constitution of A, then non-A is not extrinsic to A, but is *intrinsic* and *constitutive* of A. This means that A is *in itself* A *et* non-A. In other words, any determined identity, as A, is in itself a contradiction.

How can we understand this fatal conclusion? How to understand the contradiction? The conclusion ceases to be fatal if the contradiction, too,

18. Dewey and Bentley (1949), for example, use the concept of "transaction" to point to the primacy of relation with respect to the related terms. On the other hand, Morin (2008) refers to the concept of "complex thought" to indicate the same primacy of the relation with respect to the related terms.

is understood as an act, the *act of its own self-contradicting*, since the being of a contradiction is and is not at the same time.

The determinate identity is an "act", both when it is grasped in its *act of self-referring to that which is other from itself* and when it is grasped in *its own self-contradicting*. This act shows that the determinate identity which the empirical–formal universe considers as a *status*, is instead dynamic in itself. In other words, it is its own *continuous self-transcending*, its own *continuous going beyond itself*.

We could say that any determination is the *act of its own self-transcending,* and that this act is the same for each of them. Thus, in the *unity of the act* the multiplicity of determinations is sublated, because *with respect to this same and unique act, the difference that exists between the determinations is neutralised*.

To clarify this point further, we can say that any determinate identity appears as simple, and for this reason seems to be an immediate being, or, in other words, it seems to be autonomous and self-sufficient. However, its self-sufficiency becomes evident because it is determined only by virtue of the *difference,* and this compels it to *go beyond itself to become effectively sufficient*.

The ordinary consideration maintains that it is sufficient *to unify* the determinations, i.e., to place them in a *web of nexus* which forms a *system*, in order to overcome the insufficiency of each of them. In our view, by contrast, the union of two insufficient beings only produces a double insufficiency, not an *effective sufficiency*.

If the determinate identity is *its own self-referring*, the relation cannot be thought of as a *middle term*, which would reproduce the immediate identity. On the contrary, the relation is precisely the *act of self-referring* in which the determinate identity is resolved, which thus appears to be nothing but a *sign*, since, as a sign, it consists in "being in reference to" an other.

IX. The problem of "inseparable" entities and the unity of entangled particles

After the previous considerations, we think it is now essential to go back to the problem of the *inseparability* of determinations and, in particular, of *entangled* particles, which constitutes the primary object of our investigation.

The question that we must ask is the following: should we understand inseparability as existing between *two* entities or, on the contrary, as the characteristic of a *unique and same reality*?

From what we said concerning the determined identity and the concept of relation, it is clear that no entity can be hypostatised, but it must be understood in its "self-referring": for this reason, we can consider it as a sign. Its "self-referring", moreover, must be understood as an "act", so that the inseparability must be understood as the *unity of the act of self-referring* in which difference and multiplicity disappear.

We could reach the same conclusion following a different path. Indeed, we could consider the theme of "inseparability" and notice that, if it is understood as existing between *two entities*, then it would be a *false* inseparability.

In fact, entities *must have been separated* in order to be effectively *two*, and in order to say that the inseparability exists between them, but this is nonsense. The same argument can be applied if we speak, in the plural, of "inseparable entities". When Zeilinger, referring to the entangled particles, says that "the two particles have no independent existence", he is assuming that one is dealing with two particles, but if they are two particles, then the separation has already been operated, and it does not make sense to speak of inseparability.

The only option, thus, consists in understanding the inseparability as the *property of a reality that is unique,* and in taking the two particles to be *two abstract sections* of it. It is a unique reality because the separation of this unique reality leads to unintelligible entities, which are intelligible only to the extent that they are connected to their *unitary ground*.

Only to the extent that the *inseparable* is resolved in the two particles that represent the terms of the relation that binds them is the one reduced to the *synthesis* of terms, and the *unity* to *the unification*. But this is the error!

Indeed, the *entanglement*, as a noun, indicates that a particle cannot stay without the other, so that they can be placed at a sidereal distance and seem *independent*, but they are not independent, since one is in a *structural relation* with the other, and since the relation is the *act of their reciprocal self-referring*, which is unique for each of them.

Between them, thus, there is no *unification*, in the sense of the *ordinary relation*, which preserves the duality of the related terms. Instead, they represent a true unity, which can only be understood in the sense of the *ablatio alteritatis*.

Quantum physics and the phenomenon of *Entanglement*, which is studied in it, have great value, also for their philosophical interpretations. *True unity*, indeed, cannot be determined and thus cannot be part of the empirical–formal universe within which any speaker and agent is placed. The latter can only *point to the necessity of this unity* by saying that it is needed as an authentic ground, which must emerge beyond the system of determinations, i.e., of data.

Thanks to the *Entanglement*, true unity is detected not only as a *conceptual necessity*, but also as *ultra-microscopic experience*. In other words, the *Entanglement* can be considered as the experiment that confirms the *presence of true unity*, i.e., of the *ground*, also in the empirical–formal universe, not in the sense that the true unity is determined, since this would amount to denying its absoluteness, but in the sense that it allows us to determine the *function* and *operation* of unity in the empirical–formal universe.

True unity functions and operates in the empirical–formal universe because the two *entangled* particles are, indeed, a unique reality, a true unity, even if they are detected as two particles. The fact that the two particles are so entangled that between them there is no *distance*, i.e., no *difference*, attests that they do not constitute a *duality*, but a *true unity*. Indeed, that *distance/difference*, which seems attested by their physical dimension, is cancelled by the *conceptual bond*, which is expressed by the phenomenon of *Entanglement*.

Or, in other words, the level at which their difference is detected is not the same as the level at which their *undeniable unity* emerges. The latter cannot be detected, since the object of detection, i.e., the *Entanglement*, is that which is obtained by virtue of that unity.

X. Conclusion

We can infer, then, that the action exercised by a particle on another, which is immediate even when particles are at a sidereal distance, *is not only explainable but that it would be unexplainable if this "action at a distance" did not happen*.

This is so because they are *two* realities only *apparently* they only *appear* to be two realities, given that the reality is both *unique* and a *compact unity*, which is not articulated in itself and so does not reproduce the ordinary relation. As a consequence, it cannot be the case that any state perturbation affecting this reality does not affect it in its entirety. If the effects of a change are detected in two distinct entities, then this is due to the fact that detecting reality is still *intervening* on it, producing an *abstract section* of it. Indeed, that reality, which *in itself* is the *same* and *unique*, is grasped and inscribed in a relation with the subject, when the subject detects it.

This initial section, which is produced by the *relation of subject and object*, is followed by all the relations that are attributed to the objects obtained by the sections. However, the reality described as a multiplicity of "things", one in relation with the others, is a reality that depends on the intervention of the subject. As Heisenberg would remind us, this

subjective intervention determines the very constitution of the observed object, i.e., the reality we are ordinarily dealing with.

The observed object, however, is not the *objective reality*, but only the *perceived reality*, produced by the receptive and elaborative activity of the subject. Psychologists, who study perception, define the object as a "cognitive construct", to stress that it is not the *source* of perception but the *result* of the processes that constitute perception itself.

Thus, the object is not the objective reality. However, an *objective reality* there must be. Otherwise, the perceived reality would be entirely reduced to the activity of the subject. This objective reality explains why we detect reality, i.e., we model it, but we do not produce it.

To understand this *objective reality*, we cannot stop at the forms of energy which are the source of the *stimuli* that affect our sensorial receptors. If this were so, then this would still be a reality detected by the subject or by automatic systems created by the subject. This would still be a reality bound to the subject, not one *totally independent* from it, as a *truly objective reality must be*.

To understand this objective reality as *determining but not determined condition* (if it were determined, it would no longer be totally independent), we must refer to the *Parmenidean being*, that absolute being which is the *objective factor* of the perceived reality.

If we derive that which is *objective* from a *subjective detection*, then ultimate reality cannot but be described as *states superposition*, i.e., as a contradiction. On the contrary, only *being* represents the authentic objective factor, and being is absolute because it is free from any relation, be it intrinsic or extrinsic. Being is the objective reality, so that when knowledge tries to come close to it, knowledge can only grasp the *limit* of its own constructs, which try to partition what, in itself, is *one* and *absolute*.

Unity and *absoluteness* of objective reality emerge, according to us, in the phenomenon of *Entanglement*, because the latter reveals the *limit* of the concept of unity that can be attained through knowledge. Indeed, knowledge can attain *unification*, but not *unity*.

However, unity is revealed as the authentic ground when the unification becomes insufficient to explain that which is *inseparable*. Indeed, unification still keeps the duality, thus *distinction*. But distinction can always be resolved into the *separateness of distinct terms*, if one considers that any term must be thought as an identity, and thus must be thought as autonomous and self-sufficient, even if, *in effect,* it is not so.

The formal universe can describe the determinate being as immediate (as if any determination were independent from any other determination), but the conceptual consideration grasps it in its intrinsic mediation (i.e., in *its own self-referring* to another determination), which concerns

any immediate being, and counts as the *act of self-transcending* of each determination.

This *act* is the *same* and *unique* for any determination, and it is the unity in which all differences that characterise multiplicity are sublated. The *unity of the act*, however, can be understood only *ideally*. Indeed, to the extent that one remains on the empirical–formal level, *the unity is inevitably reduced to a unification*.

Instead, in the case of the *Entanglement* as described by quantum physics, the *function* and *operation* of the unity emerges starkly with the *impossibility of separating that which is inseparable*. It is precisely for this reason that this phenomenon has enormous importance, not only from a scientific point of view, but also from a philosophical point of view.

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