NOTAS Y DISCUSIONES

OVERLAPPING CAUSAL INTERACTIONS IN PHIL DOWE'S THEORY*

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Introduction

Many theories claiming to analyze causation have been proposed; every one of them faces some difficulty or other in relation to their adequacy in the cases of everyday use of causal terms as well as in examples related to scientific discovery.

In two papers published in 1992, Phil Dowe put forward a theory of causation[1], the *Theory of Conserved Quantities*, which draws on the theory proposed by Salmon (1984). Both Salmon's and Dowe's proposals analyze causation in terms of causal processes and interactions[2]. This view should be distinguished from that of other authors whose theories analyze causation as a relation between events[3].

According to Dowe, there are two ways of analyzing causation[4]. The first is *conceptual analysis*, which is the attempt to explicate the notion of causation as it is used in everyday language. The second is *empirical analysis*, which tries to determine what processes, entities and relations existing in nature make up the causal structure of the actual world[5].

Even though his theory, as it is formulated in the papers of 1992, already contains the bases upon which he attempts to account for causation,

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[1] See Dowe (1992a) and (1992b).

[2] Salmon, (1984), p. 178, analyzes the example of a window broken by children playing baseball as follows: Two causal interactions are involved, the bat hitting the ball and the ball hitting the glass; and one causal process, the ball moving through space.

[3] See Lewis (1973a) and (1974b), and Swain (1978).

[4] See Dowe (2000), chapter 1.

[5] We prefer to use "actual world" instead of "objective world" used by Dowe.

in 2000 Dowe[6] develops the theory to a point that allows a more detailed application to particular cases.

In this paper we present (Section 2) some counterexamples that the theory cannot solve (either in its initial or its more detailed formulation) and we show how a whole family of counterexamples can be obtained. In Section 4 we analyze the kinds of entities, processes and interactions that are candidates for the role of causes and effects. In Section 5 we show how the same kind of counterexample can be found in a type of case that only appears in the more detailed theory. Finally, in Section 6 we propose a way in which Dowe's theory could be made immune to this family of counterexamples and analyze the possible costs of this solution. The theory is briefly described in Sections 1 (initial formulation) and 3 (more detailed version). In Section 7 we mention some remaining difficulties of the theory.

1. Dowe's initial theory

Let us represent the history of an object as a line in space-time (Minkowski space) as shown in figure 1. This line is the world line associated with that object. Every point in that world line corresponds to the position of the object at a given instant. World lines parallel to the time axis indicate objects at rest; inclined ones represent moving objects. The slope cannot be greater than that corresponding to the speed of the light. In this way a past and future cone for every point in Minkowski space is obtained. An object is every entity in the ontology of the current scientific theory or of common sense[7].

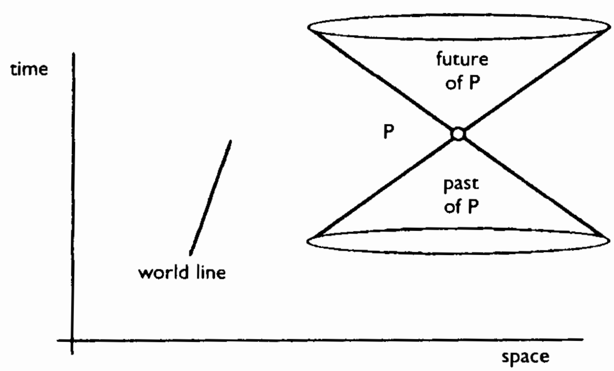

FIGURE 1

[6] See Dowe (2000).

[7] We thank Horacio Abeledo for pointing out to us that this representation should include all space-time entities whose dimensions are considered negligible in the description, so that the entity can be taken as a point in Minkowski space.

According to conservation laws of current theories, there are some quantities that are conserved not only along a world line but also in some interaction represented by world line crossings. Mass-energy, linear momentum, charge, etc., are examples of conserved quantities.

Based on the conservation of these quantities, Dowe starts to build his theory with the following two definitions:

- CQ1. A *causal process* is a world line of an object that possesses a conserved quantity.
- CQ2. A *causal interaction* is an intersection of world lines that involves exchange of a conserved quantity.

When a causal interaction takes place, there are incoming and outgoing processes (essentially interchangeable). Since asymmetry considerations are not involved in our present discussion, we will not deal with the way Dowe establishes cause-effect asymmetry[8].

"An exchange occurs when at least one incoming process and at least one outgoing process undergoes a change in the value of the conserved quantity"[9], and the exchange is governed by the conservation laws. In this way, causation between causal processes is a causal interaction between incoming processes and outgoing processes, namely an intersection of world lines where an exchange of a conserved quantity takes place.

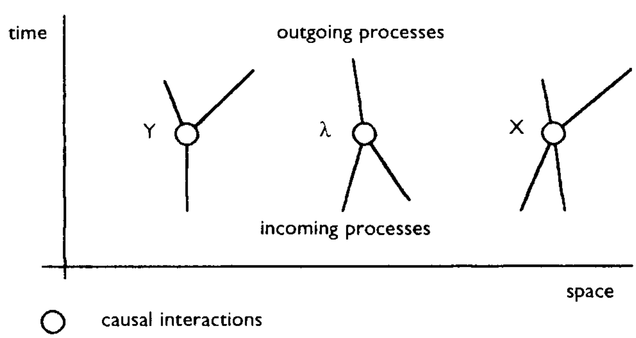

FIGURE 2

Intersections of world lines in the diagram can show different shapes; the simplest ones are the following:

Y type processes: one incoming process and two outgoing processes,

[8] See Dowe (1992b).

[9] See Dowe, P. (2000) p. 92.

- λ *type* processes: two incoming processes in a causal interaction and one outgoing process, and
- *X type* processes: two incoming processes in a causal interaction and two outgoing processes.

One of Dowe's examples follows: a nitrogen atom is hit by an α particle and an oxygen atom and a proton are produced. The nuclear equation for this transmutation reaction is:

$${}^{4}_{2}\mathrm{He} + {}^{14}_{7}\mathrm{N} + \mathrm{Q} \mapsto {}^{17}_{8}\mathrm{O} + {}^{1}_{1}\mathrm{H}$$

where Q represents the extra energy needed for the interaction.

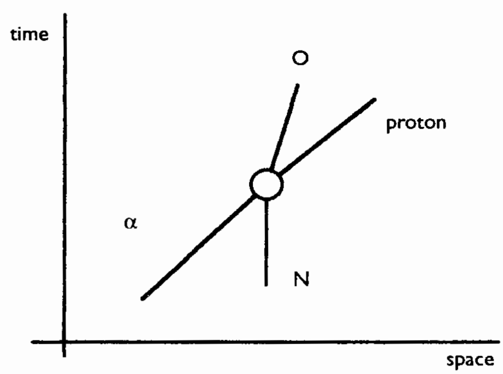

FIGURE 3

Applying the definitions we see that:

- world lines representing the α particle and the nitrogen atom are the incoming processes;
- world lines representing the proton and the oxygen atom are the outgoing processes;
- the intersection of world lines of the incoming processes with world lines of the outgoing processes constitutes the causal interaction;
- one of the conserved quantities relevant in this causal interaction is electric charge;
- electric charge is exchanged between incoming and outgoing processes; in particular, the total charge of the incoming processes is equal to the total charge of the outgoing processes; an exchange has taken place;
- each process represented by a world line is a causal process since the nitrogen and oxygen nuclei as well as the α particle and the proton possess electric charge.

In everyday causal language, we would say that bombarding the nitrogen atom with the α particle caused the production of oxygen[10].

2. A family of counterexamples[11]

Let us consider a case in which two bodies, A and B, collide in a certain instant. In the same instant one of them, say B, spontaneously emits an α particle. According to the reasoning used in the previous example we can say that:

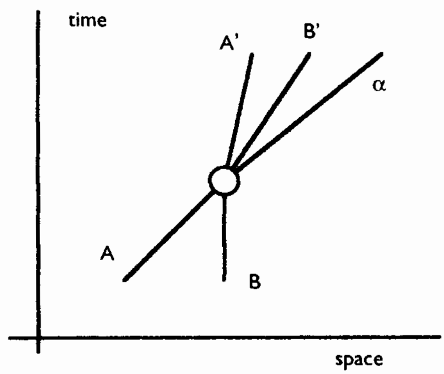

FIGURE 4

- the processes involved are causal processes since they are world lines of objects (bodies A and B, and the α particle) that possess conserved quantities, linear momentum and electric charge,
- the collision is a causal interaction because it is the intersection of the world lines of the incoming processes (the colliding bodies with their linear momentum) and the outgoing processes (the bodies after the collision and the α particle, with their momentum),
- in this causal interaction linear momentum and electric charge are exchanged.

In the usual causal language we would say that the collision of the bodies caused the emission of the particle. However, in the light of currently accepted scientific theories we are not willing to accept that state-

[10] It must be kept in mind that we have not considered the question of asymmetry; therefore the decision as to which processes are to be considered causes or effects is for the moment arbitrary.

[11] The counterexample presented in this section, as well as the solution proposed in Section 6, originate in Paruelo (1997).

ment because we consider that both the collision and the emission are independent processes. That is to say, it seems in the example that Dowe's theory establishes a case of causation that does not fit in the causal structure of the actual world.

Let us analyze the structure of this counterexample. We see that the causal interaction could be analyzed as a coincidence of two independent causal interactions: the collision and the spontaneous emission (see figure 5). Two causal interactions, one of type X with another of type Y. In the first causal interaction (collision) the relevant conserved quantity (that is, the one that is exchanged between incoming and outgoing processes) is linear momentum. Instead, in the second (spontaneous emission), both linear momentum and charge are relevant: incoming process B exchanges linear momentum and electric charge with the outgoing processes B' and α particle.

Also, the coincidence of both causal interactions in one point of space time has the following consequence regarding the exchange of linear momentum: the α particle participates in an exchange of linear momentum with incoming processes which include a body (A) which was not present in the Y type process. Therefore the two causal interactions get mixed in a way that, according to the theory, leads us to judge that the collision of body B with body A has caused the emission of an α particle.

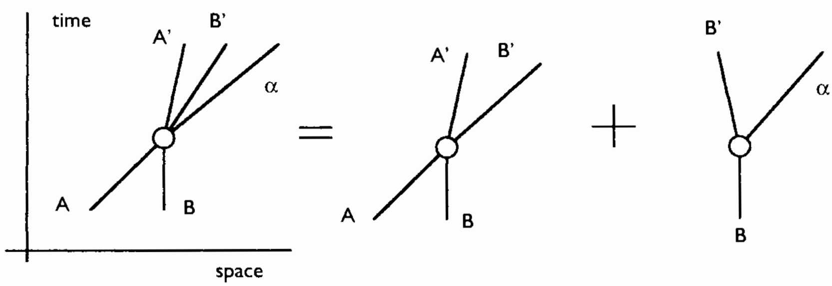

FIGURE 5

A similar example could be that of a fly alighting on a time bomb precisely in the instant at which the device has been set to explode. The intersection of world lines of the bomb and the fly is, according to Dowe's theory, a causal interaction in which great amounts of energy and linear momentum are exchanged (with sad consequences for the fly). Here two X-type processes coincide in the same space-time point.

Other counterexamples such as these can be built where independent causal interactions take place in the same point of space-time and at least one of the quantities that are exchanged in one of the interactions is also exchanged in the other one. In this way, for the theory of conserved quantities it becomes impossible to discriminate when two independent causal interactions coincide in space-time.

Besides, a feature derived from their independence is that there exists an exchange of a conserved quantity in one of the interactions that is not relevant for the other one. For example, the exchange of linear momentum is not relevant for the exchange of electric charge in the case of the emission of the α particle, and the quantity of linear momentum exchanged between the fly and the bomb is not relevant to the quantity exchanged between the explosive and the detonator.

3. Dowe's detailed theory

Before going into Dowe's more detailed theory, it should be made clear that, although details are added to the theory in Dowe (2000), the detailed theory does not contradict the initial version. Rather, the added depth allows for its application to a wider domain of cases[12].

In the detailed exposition, Dowe (2000) postulates:

(i). "An *event* is a change in a property of an object at a time (...); or a related simultaneous change in more than one property of more than one object at a time, and so on[13]."

(ii). "A *fact* is an object having a property at a time or over a time period[14]."

He then goes on to indicate under what condition these facts or events are involved in cases of causation:

(iii). "such facts and events, if they enter into causation, must involve conserved quantities or supervene on facts and events involving conserved quantities."

(iv). "We will also distinguish between the manifest and the physical (...). So we say that manifest causal facts supervene on physical causal facts[15]."

[12] For example, it attempts to account for causation in cases in which omissions or preventors appear. See Dowe (2000), chapter 6. Regarding the symmetry Dowe suggests between cases of causation with omissions and preventors, we have shown (11th. International Congress of Logic, Methodology and Philosophy of Science, Jagiellonian University, Cracow, august 20-26, 1999) that this symmetry holds for events but not for states of affairs that play the role of causes or effects.

[13] Dowe (2000), pp. 169-170.

[14] Ibid, p. 170.

[15] Ibid, p. 170.

Then he postulates what is a causal connection between causal interactions:

(v). "Interactions I_1, I_2 are linked by a causal connection by virtue of causal process *p* only if some conserved quantity exchanged in I_2 is also exchanged in I_1, and possessed by *p*[16],"

and what is a causal connection between facts:

(vi). "There is a causal connection (or thread) between a fact q(a) and the fact q'(b) if and only if there is a set of causal processes and interactions between q(a) y q'(b) such that:

(1) any change of object from a to b and any change of conserved quantity from q to q' occur at a causal interaction involving the following changes: Δq(a), Δq(b), Δq'(a), and Δq'(b); and [17]

(2) for any exchange in (1) involving more than one conserved quantity, the changes in quantities are governed by a single law of nature.

(vii). The need for (2) is to rule out cases where independent interactions occur by accident at the same time and place[18]."

4. The candidates for causal relata

In quotation (i) describes the change of a property as an event; and in (iii) we find that events, as well as facts, can enter into causal relations. Therefore, changes in values of properties can play the role of causes or effects. According to (ii), objects can also be causes and effects. Facts and events can be causes or effects if they involve conserved quantities, or if they supervene[19] on facts that involve such quantities.

[16] Ibid, p. 171.

[17] Our correction to the version appearing in Dowe (2000): "Δq(a), Δq(b), Δq'(a), and Δq'(a)"; the last change is obviously an involuntary error. We shall assume throughout that our correction is Dowe´s intended version.

[18] Dowe (2000) pp. 171-172.

[19] Dowe (2000), p. 170, uses the notion of supervenience as defined by Armstrong (1997), p. 11: "entity Q supervenes upon entity P if and only if it is impossible that P should exist and Q not exist, where P is possible. *Impossibility* here is the strongest or absolute impossibility, the sense in which (most philosophers would say) it is impossible that 7+5 should be equal 11. *Possibility* is the weakest possibility, the pos-

Dowe makes a distinction between manifest and physical properties, and admits causation between facts or events that involve manifest properties as long as they supervene on physical properties. It is therefore possible to analyze the more common cases of causation in terms of Dowe's theory. Thus the theory may be applied both to the everyday uses of the relation and to its specific application to domains such as, for example, scientific explanation. Even when some manifest fact does not involve conserved physical quantities –take, for example, the color of an object– it can appear as a cause or effect if it supervenes in properties of its parts and these properties involve conserved quantities such as, for example, selective reflectivity. These properties are not "color" but are a substrate of the property we call "color". That is to say, manifest facts can enter in causation relations if they supervene on facts that do involve conserved quantities. So that it can be said that an object causes another object, that an event causes another event, that a change in a property causes the change of another property, etc.

In summary, there are three levels of candidates to be bearers of causal roles:

1. values of conserved quantities that are exchanged: for example, the value of the quantity of linear momentum of a billiards ball at an instant is responsible for the value of the same quantity at a later instant[20];
2. facts (objects with properties) or events that involve conserved quantities: for example, photon *a* with some energy with colliding with atom *b* is a cause of the resultant atom with a certain final energy[21].
3. facts (objects with properties) or events that do not involve conserved quantities but supervene in facts that do involve conserved quantities: for example, a green billiards ball in the cause of the image in a photograph[22].

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sibility, for instance, that the Earth and its inhabitants do not exist". In Dowe's view, "manifest causal facts [in the examples, those associated to macroscopic characteristics] supervene on physical causal facts" [associated to microscopic processes and properties], though he notes "that the Armstrong supervenience thesis does not assert that everything that supervenes on a genuine physical causal fact is a causal fact".

Although the present analysis of Dowe's theory does not depend on the notion of supervenience used by Dowe, we believe this point deserves to be studied closely. The same can be said of the criterion of identity for objects needed for the theory.

[20] Ibid, p. 172.

[21] This formulation is the most similar to the first part of the example found in Dowe (2000), p. 173 and analyzed by us in the following section.

[22] Dowe does not present explicit examples of causation between objects with properties supervening on physical properties. Ibid, p. 170.

5. Examples and counterexamples

We consider here two of Dowe´s examples.

Two billiards balls collide[23]. The linear momentum of the first ball (q(a) at t_1) is causally responsible for the final linear momentum of the second ball (q(b) at t_2). That is to say, the fact that the first ball has before the collision a linear momentum of 3 units is causally responsible for the second ball's having, say, 5 units of momentum after the collision. This is an example of the first level analyzed in section 4: causes and effects are values of the physical quantities involved (see figure 6).

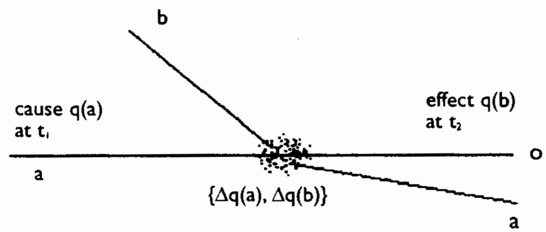

FIGURE 6

For the second level we find the following example[24]. An unstable atom is bombarded by a photon whose frequency is the absorption frequency of the atom. As a consequence the atom decays. Dowe describes the situation thus: "the cause q(a), the incident photon with certain energy, is linked to the effect q'(c), the existence of the second atom, the product of the decay" (see figure 7).

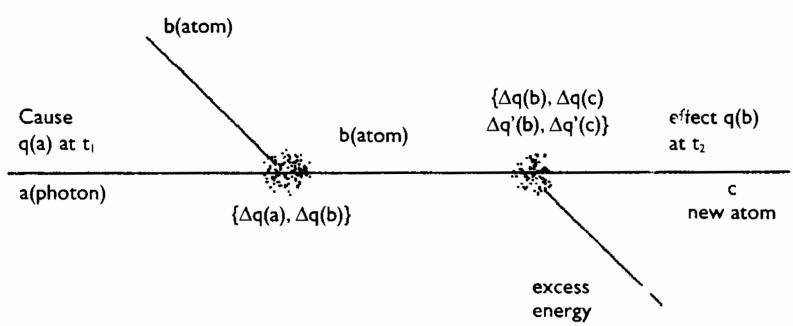

FIGURE 7

[23] This is the example we mentioned in the description of level 1. Ibid, p. 172.

[24] Ibid, p. 172.

Thus the photon with certain values of its physical quantities is a cause of the atom with certain values in its quantities. The example fits in the second level: objects causally related in virtue of their involving conserved quantities –according to quotations (v), (vi) y (vii). Surprisingly, however, Dowe refers to the effect as "the existence of the second atom, the product of the decay."

According to the above definitions it is clear that there is a causal link between q(a) y q'(c), that is between «the quantity of energy q of the incident photon» and «the quantity of charge q' of the second atom» (see figure 7). But Dowe refers to q'(c) as "the existence of the second atom"[25].

Thus Dowe intends to account for the judgment that «the photon caused the decay of the atom, or the emission of a new atom». However, the new atom has other properties besides those exchanged here, some of them conserved quantities such as linear momentum. These quantities do not enter in the interaction, at least not in the causal aspects described by Dowe. It must be assumed that, from the properties described in the interaction between «the energy of the incident photon» and «the charge of the second atom, product of the decay» the causal relation between "the incident photon" and "the product of the decay" mentioned by Dowe must be inferred.

Finally, we shall see what happens when we apply the detailed theory to the case of the counterexample presented in section 2. We shall show that the detailed version does not eliminate the difficulties. Moreover, the difficulties seem to extend further than we had shown. Let us reformulate the example in terms of the second version, adding a time lag between collision and emission to avoid the superposition of interactions.

Two billiards balls *A* y *B* collide at instant t_1. Ball *B* does not interact with other bodies until the instant t_2, in which it emits spontaneously an α particle. We now follow Dowe´s reasoning, which is similar to that employed in the previous example. Both ball *A* and ball *B* possess linear momentum before the collision (manifest property) and there is exchange of momentum during the collision, so that after the impact *A'*, *B'* (the balls after the collision) possess different values of the conserved quantity. At t_2, *B'* emits the α particle and there is also an exchange of linear momentum. After t_2, *A'*, *B"*[26] and the α particle possess different values of the same conserved quantity (see figure 8).

According to Dowe, in this case there are changes of value in the conserved quantity[27], and also changes of object. In virtue of the causal links between linear momenta before and after the collision we can say that «the

[25] See Dowe (2000) p. 173.

[26] We use *B"* to denote ball *B* after the emission, however, that must not be interpreted as implying any commitment regarding the identity problem mentioned in note 19.

[27] According to the notion of supervenience mentioned in note 19, we can say that the linear momentum of the ball supervenes on the linear momentum of each of the particles that compose it (physical properties).

linear momentum of ball *A* is a cause of the linear momentum of ball *B*"» and also that «the linear momentum of ball *A* is a cause of the linear momentum of the α particle».

In the example the electric charges of *B*', the *B*" and the α particle are also involved. Therefore there is a causal link between the charge of *B*' and the charges of the α particle, of *B*", and of *B*'. But there is also a causal link between the linear momenta of ball *A* and of the α particle. Following Dowe, we could say that «*B*' is a cause of the emission» and that «*A* is a cause of the α particle». However, Dowe would be willing to accept the first but not the second judgment. Independently of the discussions that might arise as to the acceptability of the first, probably everybody would agree that the second judgment is inadmissible. There is clearly no relation between ball *A* and the emission of the particle[28]. It is not clear, however, how Dowe´s theory could avoid the second judgment.

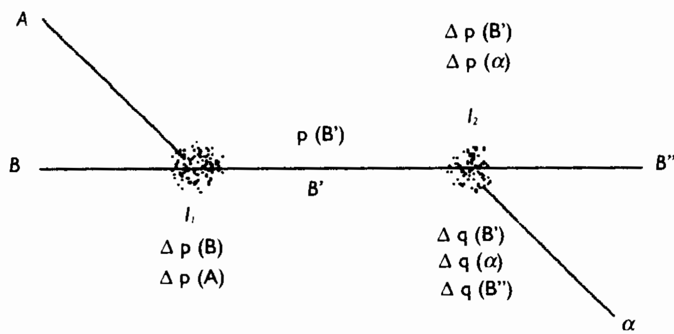

FIGURE 8

Dowe considers[29] this is avoided by demanding that "for any exchange (...) involving more than one conserved quantity, the changes in quantities are governed by a single law of nature[30]." However, in the example this requirement is satisfied. In our opinion, when there is a causal superposition that involves facts or events of the second or third level (according to our characterization of section 4), the problem has not been solved by the detailed theory even though it was devised to avoid these difficulties.

6. Counterexamples: a way out

If the conserved quantity theory is to be useful for the ends for which it is intended (for instance, to give an account of the causal structure of the

[28] As we concluded in the case of the original version of Dowe´s theory.

[29] Explicitly in quotation (vii) as well as in personal communication with the authors.

[30] See Dowe (2000) p. 172.

actual world), it should be possible to select a tool capable of discerning genuine cases of causation from non-genuine cases such as those presented previously as counterexamples. That is, the tool should enable us to avoid to consider as cases of causation cases in which there is space-time superposition of causal interactions (counterexamples presented in section 2) as well as cases in which interactions in separate points of space time seem to be causally connected (counterexample presented in section 5). This tool should be capable of selecting individual causal interactions, that is, those that are not superpositions of other interactions. But this means that we must not search for a tool that allows to decompose any interaction as a combination of other interactions, but rather for a tool that selects undecomposable interactions that could be identified as independent components.

One such tool could be the use of counterfactual conditionals. Thus, to establish if some incoming processes are causes of some outgoing processes we should analyze the counterfactual associated to the interaction; that is we should demand that the counterfactual "if the incoming process (or interaction) had not taken place, the outgoing process (fact or event) would not have occurred" be true. In the case of our examples, both the counterfactual "if bodies A and B had not collided, the α particle would not have been emitted" and "if the fly had not alighted on the bomb it would not have exploded" are clearly false. Similarly, for section 5, the counterfactual "if ball A had not collided with ball B at t_1, ball B would have emitted the α particle at t_2 " is also false.

The use of causation as a criterion of evaluation of counterfactuals[31] is obviously a luxury we cannot afford. But fortunately David Lewis (1973b) has tried to present an analysis of counterfactual conditionals that is independent of causation, with the intention of using them as a tool useful in the analysis of causation[32]. The counterfactual analysis of causation presents serious difficulties, and has proven unsatisfactory in our view[33], but it could serve as a complementary tool allowing, as we have said, the distinction between different causal interactions in cases such as our counterexamples, thus completing Dowe's theory of conserved quantities.

The use of counterfactuals is not altogether foreign to the theory, since Dowe himself uses it in the analysis of causation by omission[34]. In Dowe's[35] view, however, it is an undesirable deviation from his original program, in which he intended to find an analysis of causation in terms of physical theories only. Nevertheless, as we have pointed out, his theory has al-

[31] Kvart (1986) presents such a criterion.

[32] See Lewis (1973a).

[33] See Flichman (1989) and (2000); Miguel and Paruelo (1997); Abeledo (1995) and (2000).

[34] Dowe uses counterfactuals to distinguish genuine causation between events or facts from causation* between omissions. See Dowe (2000), chapter 6 (see also our note 12) and, more recently, Dowe (2002).

[35] Personal communication (1999).

ready lost its intended homogeneity by recurring to counterfactuals in the case of causation by omission[36]. Our proposal expands the non-physical component of his theory thus increasing that deviation.

One condition should be imposed in case Lewis's or some other theory were to be used for the evaluation of counterfactual conditions in connection with CQT. In the evaluation of counterfactuals the conservation law that is relevant to the causal interaction under analysis should not be abandoned.

7. The role of scientific theories

A more general objection to Dowe's theory is that an analysis of causation based on processes described by current scientific theories is liable to be affected by theory changes in the scientific disciplines involved[37].

Dowe's response to objections of this sort in the distinction mentioned above between empirical analysis and conceptual analysis. It is clear that conceptual analysis should not change with every change of scientific theories. But Dowe's goal is empirical analysis. He is trying to study nature empirically to find which aspects constitute causal interactions. In this sense Dowe's (or Salmon's) findings run the risks of any other scientific discovery. Dowe holds the view that a more profound understanding shall be gained by following this road than by treading others that disregard scientific theories[38]. Dowe's conception seems to consider the real world as the one described by the current physical theory, which would indicate a commitment to a strong physical realism.

Nevertheless the problem cannot be solved so easily. Analyzing what it is that we usually call "causation" and what exists in nature, the two types of analysis Dowe mentions are, as Dowe himself acknowledges[39], two aspects that can not be sharply separated.

8. Conclusions

Dowe's theory represents and analyzes individual causal interactions correctly when they do not seem to result from a superposition of several interactions in space-time.

[36] This contrast was analyzed in Miguel, "Causación física: ¿con o sin contrafácticos?", III Jornadas de Investigación para Profesores, Graduados y Alumnos, Universidad Nacional de La Plata, La Plata, November, 2000.

[37] This is an objection presented by Eduardo Flichman (1995) both against Salmon's and Dowe's theories.

[38] Personal communication (August 1998).

[39] See Dowe (2000), chapter 1.

In the case where two or more independent causal interactions take place in the same space-time point, the theory of conserved quantities does not provide for a distinction between the interactions and describes the situation as a single causal interaction.

In losing the distinction between the two coincident interactions, the theory could allow the identification of the incoming processes of one interaction as causes of the outgoing processes of the other interaction and therefore provides an erroneous description both from a scientific and from an intuitive point of view.

This is a general difficulty; that is to say, we have not just found a situation that is anomalous for the theory, but rather some general characteristics that would make any particular case an anomalous case. The difficulties extend to causally connected interactions that occur in different points of space-time connected by small timelike intervals.

On the other hand, since we consider Dowe's theory to be among the theories that are best equipped to account for causation as a process that exists in nature, we suggest a complementary tool that could complete the theory so as to avoid the family of counterexamples here presented. The tool is the use of counterfactual conditionals, even though it implies a new deviation from the initial intention of achieving a purely physical account of causation.

These conditionals have been under study for several decades. An adequate evaluation should take into account the conservation laws that are the basis of the theory of conserved quantities. This evaluation process is available, so that the only needed would be to extend to these cases the use of counterfactuals, that Dowe already used in the case of causation by omission.

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ABSTRACT

La teoría de Phil Dowe (2000) intenta dar cuenta de la causalidad en el marco de las teorías físicas actuales con un análisis centrado en procesos e interacciones causales. En este artículo se presentan algunos contraejemplos a dicha teoría en casos de superposición de interacciones causales y se muestra de qué manera puede obtenerse toda una serie de ellos. Se analiza también qué tipo de entidades, procesos o interacciones son candidatos a desempeñar el papel de causas y efectos en el marco de la mencionada teoría y se muestra finalmente cómo la teoría de Dowe podría hacerse inmune a esta familia de contraejemplos y cuál sería el costo de esta posible solución.