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Logical Interpretation of 1894 Pierre Curie's Paper about Symmetries in Theoretical Physics

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Abstract. Curie's 1894 paper is examined through its use of propositions of intuitionist logic. Its metaphysical and theoretical aspects are made manifest. Its metaphysical part turns out to be insufficient. Its theoretical organization is not an axiomatic organization as it appears at first sight, but a problem-based organization, composed by doubly negated propositions, *ad absurdum* proofs and the application of the principle of sufficient reason. Or better, its organization is a mixture of the characteristics features of both kinds of theoretical organization. In an Appendix a great part of the intuitionist propositions of Curie's paper are listed and their theoretical impact is discussed.

Keywords: Symmetries, Curie's principle, Heuristic principles, Doubly negated propositions, Problem-based organization, *Ad absurdum* proofs, Principle of sufficient reason, Constraints on the theory of symmetries

1. Pierre Curie's paper on symmetries: its essential content

The present paper examines in details Curie's paper (Curie 1894) aimed at transferring the knowledge on symmetries acquired by crystallography into theoretical physics. Previous partial examinations are those of (Radicati 1987, p. 201) and (Castellani & Ismael 2006, sect. 2).

Let us start with a characterization of his kind of mathematics. About this topic he writes: "Nous ne nous occuperons ici que d'un système limité" (Curie 1894, p. 394); as a fact, he makes use of the mathematics of finite groups. It is clear that, since this theory is entirely finite, his mathematics is without idealistic notions; hence, Curie's choice is for the potential infinity, in alternative to the metaphysical kind of infinity, the actual one.

The paper is composed by seven sections:

> [p. 393 :] I. [Introduction]. [p. 394 :] II. Opérations de recouvrement [= transformations] et éléments de symétrie. [p. 398 :] III. Les groupes d'opérations de recouvrement. [p. 400 :] IV. Dissymétrie [= aujourd'hui appelée asymmetrie] caractéristique des phénomènes physiques [(champ gravitationnel, champ électrique, champ magnétique)]. [p. 409 :] V. Superposition des causes de dissymétrie [données par deux distincts phénomènes] dans un même milieu. [p. 412 :] VI. Liaisons [non absolues] entre les symétries caractéristiques des divers milieux. [p. 414 :] VII. En RESUMÉ [les principes métaphysiques de cause et effet dans le sujet traité].

These titles and their order of illustration lead to think that the paper is finalized to present some practical considerations on symmetries, by starting from the well-established knowledge of symmetries in crystallography. But Curie adds a theoretical framework. For instance, at the starting of sect. IV he abruptly states five "propositions" whose contents are highly theoretical in nature:

> *La symétrie caractéristique d'un phénomène est la symétrie maxima compatible avec l'existence du phénomène. / Un phénomène peut exister dans un milieu qui possède sa symétrie caractéristique où celle d'un des intergroupes [= sous-groups] de sa symétrie caractéristique*e. / Autrement dit, certains

> éléments de symétrie [du milieu] peuvent coexister avec certains phénomènes, mais ils ne sont pas nécessaires. Ce qui est nécessaire, c'est que certains éléments de symétrie n'existent pas. *C'est la dissymétrie qui crée le phénomène…* / *Lorsque certaines causes produisent certains effets, les éléments de symétrie des causes doivent se retrouver dans les effets produits. Lorsque certains effets révèlent une certaine dissymétrie, cette dissymétrie doit se retrouver dons les causes qui lui ont donné naissance* (pp. 400-401; here and in the following the Italics are in the quotation of Curie's text).

Then he interprets through symmetries some physical phenomena concerning mechanical motion, light phenomena, and some physical fields (gravitational, thermal, electric and magnetic ones).

At last (sect. VII) Curie says that he summarizes ("En RÉSUMÉ") the results of his illustration ("conclusions"). Also this final part is not consonant with the modest titles (listed in the first quotation) of the seven sections of the paper. Here, he presents as his results two propositions which are highly theoretical in physics and even metaphysics: *Il n'est pas d'effet sans causes… / Il n'est pas de cause sans effets* (p. 414).

Hence, his introduction of some usual ideas of crystallography into theoretical physics wants to suggest not only some pragmatic rules of phenomenological nature, but also a framework of theoretical and even metaphysical nature.

2. The metaphysical part of Curie's paper. Is it a preparation of an axiomatic-deductive theoretical organization of his physical theory?

Curie's paper includes the following theoretical notes: two theoretical parallelisms, five theoretical "propositions", three *ad absurdum* arguments and two "conclusions" on the metaphysics of cause-effect concerning symmetries. They are inserted in the sections I, IV, V, VI, VII. These theoretical notes are interspersed in the text without an order which is foreseeable by the reader. Does the complex of such notes constitute a systematic theory?

Let us examine the paper according to the characteristic features of the traditional kind of a theoretical organization, the deductive-axiomatic one (hereinafter referred to as AO), possibly equipped with a metaphysical premise. The paradigmatic theory of Curie's time, Newton's mechanics, was based on metaphysical notions: absolute space and time, force-cause and universal gravitational force intended as God's intervention on the world. Curie reiterates this philosophical attitude by introducing since the second page (Curie 1894, p. 394) a distinction of the physical phenomena in two groups, called "causes" and "effects" and then wants to connect them together.

Being metaphysical in nature, the words "cause" and "effects" have to be conceived as premises of a physical theory, which is organized as a set of propositions drawn from some metaphysical and physical principles. Curie does not worry of committing his illustration to the metaphysics of the notion of "cause". But we know that in theoretical physics a connection cause-effect is problematic, since there is no way to experimentally verify whether a phenomenon is the cause of another one or not (Andreas and Guenther 2021). Anyway, the presented metaphysics connection is strange. At the end of the paper, in sect. VII, Curie suggests some metaphysical considerations:

> Les premières sont des conclusions fermes mais négatives, elles répondent à la Proposition incontestablement vraie : *Il n'est pas d'effet sans causes*. […] Les considérations sur la symétrie nous permettent encore d'énoncer une deuxième sorte de conclusions, celles-ci de nature positive, mais qui n'offrent, pas la même certitude dans les résultats que celles de nature négative. Elles répondent à la proposition : Il *n'est pas de cause sans effets*. […] les prévisions ne sont pas des prévisions précises comme celles de [curieusement, pas de la Mécanique, mais] de la Thermodynamique. On n'a aucune idée de l'ordre de grandeur des phénomènes prévus: on n'a même qu'une idée imparfaite de leur nature exacte. Cette dernière remarque montre qu'il faut se garder de tirer une conclusion absolue d'une expérience négative (p. 414).

Hence, exactly the most interesting metaphysical connection from cause to effects (in agreement with the typical logical path of an AO) is not accurate. It is a remarkable fact that he locates as second the "conclusion" expressing this typical relationship of metaphysics; whereas he locates as first the proposition going the other way around, i.e. that "going back" from effect to causes. But Curie remarks that the latter proposition sometimes fails, i.e., it is not so certain as the former one. Hence, he is well aware of this inversion of the natural order. If he had presented as first the second proposition he had to admit since his first "conclusion" that, although enounced as a metaphysical proposition, this connection cannot determine its effects as certain effects. Therefore, he is obliged to present as a premise of his physical theory a metaphysics of causes which fails to determine with certainty the effects. In the traditional metaphysics this imprecision of causes was surely unusual.

However, in previous times theoretical mechanics met a similar metaphysical imprecision. In 18th century, a force-cause acting against the direction of the caused motion was considered as an oxymoron. Hence, theoretical mechanics of that time did not deal with the notion of passive force, as friction or other resistances to the motion are. At the end of 18th century, Lazare Carnot took into account this kind of forces whose angle with velocity is obtuse. Of course, a contradictory metaphysics of force cause resulted. Notwithstanding, a physical theory was still possible because Carnot developed his mechanics after having suppressed the notion of force-cause as a "metaphysical and obscure" notion; his forces have an accurate physical definitions as weights (Carnot 1783, sect. XXXI); and later the Newtonian theoretical framework allowed to translate a passive force into a mathematical notion by merely adding in the mathematical expression of the force a new argument concerning velocity: $F(x, g(v), t)$.

Also Curie seems to look for a mathematical characterization of his metaphysical propositions when suggesting a parallelism ("de même" = similarly) between the metaphysical link cause-effect and the mathematical connection between the physical quantities composing an equation representing a phenomenon, like the equation $f = ma$.

> Enfin, lorsque certaines causes produisent certains effets, les éléments de symétrie des causes doivent se retrouver dans les effets produits. De même, dans la mise en équation d'un phénomène physique, il y a liaison de cause à effet entre les grandeurs qui figurent dans les deux membres (Curie 1894, p. 394).

Notice that this parallelism may be contested because he refers to the specific case of an equal number of symmetries in the cause and in the effect, although we have learnt that the effects may have more symmetries that the cause (see the above quotation of p. 414); i.e., a dissymmetry causing a phenomenon of symmetry attributes a role of a cause to what metaphysics cannot take into account: a shortage (of symmetries).

In conclusion, Curie's paper presents a defective relation between "cause" and "effect"; these notions lack of a clear logical connection (and a mathematical translation); hence, they represent an odd and partial metaphysics. Therefore, Curie's above parallelism suggests a hint for further speculations, not a translation of the metaphysical part of his paper into a mathematical part of a physical theory.

Moreover, let us remark that he calls these propositions "conclusions". This word suggests that the metaphysical part of Curie's paper wants to acquire certain propositions to be put as premises to a physical theory of symmetry; instead Curie's metaphysical "conclusions" are partially disconnected from his physical theory of symmetry; they cannot play the role of assured metaphysical premises of a physical theory. This disconnection was a reason of the obscurity of his paper whose interpretation was debatable along a century and more.

Last, but not least, after Einstein's 1905 "revolution" in the foundations of theoretical physics we should overlook all metaphysical notions of Curie's paper as ininfluential ones for focusing the physical contents of his paper.

3. Is the theoretical organization of Curie's physical theory an axiomatic-deductive one?

Owing to the similar metaphysical attitude of the original Newton's theory, also Curie's paper seems to illustrate an AO theory, as Newton's theory is. As a fact, almost all scholars have seen as "laws" Curie's two "conclusions". Nevertheless, Curie does not qualify as "laws" or "axioms" what he rather modestly calls "propositions" and "conclusions"; moreover, in pp. 409 and 410 he refers to merely "les conditions de symétrie". All these Curie's words do not conform to an AO.

Now let us investigate on the five "propositions" starting the theoretical part of the paper (pp. 400-401). They are introduced by Curie without any justification,[1] although they are not evident propositions; at most, they may be considered as plausible propositions. Are they the axioms of a physical theory? But the most important logical feature of all these "propositions" is that they are not affirmative proposition, but modal ones; they include the modal words: "compatible, peut, nécessaire, créer, doivent se retrouver, doit se retrouver" (pp. 400-401). Hence, the content of each one is not circumscribed. Owing to this fact the "propositions" cannot work as axiomatic principles of an AO theory.[2]

Worst, the "conclusions" have no unique link with physical notions; the word "cause" is specified by Curie as representing different physical notions: dissymmetry, medium, etc.; a theoretical physicist has to recognize case by case the physical connection between the stated cause and a physical notion.

In conclusion, although some propositions are expressed in an apodictic style (e.g. "*C'est la dissymétrie qui crée le phenomène*"), the presentation of Curie's paper does not conform to an AO theory.

4. The problem-based organization in Curie's paper

A previous paper (Drago 2023) showed that the notion of symmetry is equivalent to a double negation; as such it belongs to non-classical logic, in particular intuitionist logic. This fact alone suggests that Curie's paper on symmetries cannot be entirely formulated according to an AO which is managed by classical logic. Let us examine whether it may be interpreted as representing a problem-based organization (henceforth indicated with PO), which is illustrated in the paper (Drago 2012).

The first step of the theoretical development of a PO is to declare its basic problem, whose solution is found out through a new scientific method invented by the following part of the theory. As a fact, Curie does not explicitly state a problem. However, it is clear that the general problem met by the paper is whether there exist some parts of theoretical physics which present symmetries in a parallel way to those of crystallography. Moreover, a first specific problem occurs in Sect. IV: Which are the groups of symmetry of three physical fields.[3] Then in sect. V one more problem (how multiple dissymetries overlap in a same medium) occurs.

The second step of the theoretical development of a PO is an *essential* use of its typical propositions, i.e. the doubly negated propositions whose corresponding affirmative ones are lacking of evidence (DNPs); hence in these cases the double negation law fails, as it is true within intuitionist logic. As a fact, by ingenuousness Curie made use of a lot of DNPs. In the Appendix of present paper a substantial part of them are listed and discussed. It is shown that author's arguing essentially relies on the use of DNPs.

As third step of the theoretical development of a PO an author not only makes use of intuitionist logic through the DNPs, but also reasons within this kind of logic: he composes through DNPs *ad absurdum*

[1] They are introduced by means of a proposition oddly expressed in the future time: "Nous énouncerons les propositions suivantes…". Is this future time an implicit admission of their lack of evidence?

[2] Do Curie's modal words represent an improper way of speaking? No translation of all modal words into affirmative ones is apparent. For example, in the first one "proposition" the words "comparable avec l'éxistance du" can be replaced by the words "associé au", that however are again modal ones.

[3] Castellani and Ismael (2016, p. 1003) recognize the following problem: "His analysis was centered on the question: Which phenomena are allowed to occur in a given physical medium having specific symmetry properties?".

arguments (AAAs) whose conclusions are again DNPs.[4] Curie's text presents three AAAs. Let us quote them.

> Donc le champ de l'attraction newtonienne pourra se rencontrer dans un milieu possédant la symétrie de (c) ou un de ses intergroupes ; du reste, on ne peut imaginer que la symétrie puisse être supérieure à (c), car elle devrait être dans ce cas la symétrie du groupe cylindrique (a) ou celle du groupe sphérique (19) et [ça c'est absurde, parce que] le champ n'aurait pas de sens et il en serait de même des forces et des vitesses (Curie 1894, p. 403).
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> Le groupe (a) à symétrie cylindrique et le groupe (19) à symétrie sphérique sont les seules ayant pour intergroupe (c). Il n'est donc pas vraisemblable que le champ électrique puisse avoir une symétrie supérieure à (e). Ce dernier point peut du reste être démontré rigoureusement si l'on admet, comme nous l'avons va plus haut, que la force agissant sur un corps pondérable a elle-même pour symétrie caractéristique le groupe (c). Supposons, en effet, qu'une sphère conductrice chargée d'électricité soit isolée dans l'espace, puis que l'on fasse naître un champ électrique par une cause quelconque. Une force agira sur la sphère dans la direction du champ. La dissymétrie des effets doit se retrouver dans les causes qui lui on donné naissance; la force ne possédant pas d'axe de symétrie normal à sa direction, le système de la sphère chargée et du champ ne doit pas non plus posséder cet élément de symétrie. Mais la sphère chargée, considérée isolément, possède des axes d'isotropie dans toutes les directions; la dissymétrie en question provient donc du champ électrique qui ne doit pas posséder [= c'est absurde qu'il possède] d'axe de symétrie normal à sa direction. Le champ électrique ne peut donc pas avoir la symétrie cylindrique ou sphérique, et sa symétrie caractéristique est celle du groupe (e) (p. 404).
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> On voit qu'un champ de symétrie peut posséder un plan de symétrie normal à sa direction. Le champ magnétique est, au contraire, incompatible avec la présence d'un axe binaire normal à sa direction. Pour le prouver, nous allons nous servir des phénomènes d'induction. Considérons, par exemple, un fil rectiligne animé d'une certaine vitesse normale à sa direction. Un pareil système possède un axe binaire dans le sens de la vitesse. Supposons maintenant qu'un champ magnétique existe dans la direction normale au fil et à la vitesse de déplacement; une force électromotrice d'induction naîtra dans le fil. Ce phénomène est incompatible avec [= ça c'est absurde à cause de] la présence d'un axe binaire dirigé dans le sens du déplacement, c'est-à-dire normal au fil. La dissymétrie des effets doit se retrouver dans les causes; la disparition nécessaire de l'axe binaire dont nous avons parlé ne peut provenir que de la présence du champ magnétique, celui-ci ne peut donc pas avoir d'axe binaire normal à sa direction (p. 406).

Notice that these AAAs concern not one problem of a general theory of symmetries, but three distinct problems: which is the symmetry group of each of three fields: gravitational, electric and magnetic field?[5] Hence, we have three distinct physical PO theories, each one about the specific group of symmetry pertaining to a particular physical field. The occurrences of these AAAs give decisive evidence for attributing a PO to each of the three theories presented by Curie's paper.

In each of these three cases Curie matches the axes and planes of symmetry of the field at issue with those of a set of groups of symmetry. In each comparison Curie suggests an AAA for recognizing the specific group to be attributed to the physical field at issue. In the first case he states that the gravitational field "pourra se rencontrer dans un milieu possédant la symétrie de (c)" (p. 403). In the other two cases Curie makes use of another modal word, not "pourra", but "compatible" (pp. 404 and 405 for the electric

[4] A prejudice on the *ad absurdum* proof is to maintain that this kind of proof is invertible in a direct proof; yet, this inversion is possible in classical logic by translating its last proposition, which is a DNP, into the corresponding affirmative one through the double negation law, which instead fails in intuitionist logic.

[5] Curie does not attempt of showing the symmetry of the electromagnetic field, because this symmetry is the conformal group, which was beyond the scientific knowledge of Curie's time.

field and pp. 405 and 406 for the magnetic field)[6]; hence, Curie makes an essential use of DNPs; also the conclusion of each AAA, since a modal proposition corresponds to a DNP: "It is not true that the field *x* does not have the group of symmetry *y*". Notice that this proposition excludes different groups from the previously suggested one, but it does not enjoys certainty.

5. The principle of sufficient reason within a PO development and Curie's paper

The fourth step of the development of a PO theory is the application of the principle of sufficient reason (PSR) to the final predicate (a DNP) of a possibly chain of AAAs, in order to obtain a proposition of affirmative kind, the only kind of proposition which then can be accurately tested with reality and hence validated or not.[7]

Curie does not explicitly apply the PSR. However, in the first case of study Curie states the thesis to be proved through the following proposition: the symmetry of gravitational field, "C'est la symétrie du champ (c)". (p. 403). The result of the application of PSR to the conclusion of the first AAA is exactly the same proposition. Curie may have considered annoying to reiterate this same proposition after the end of the AAA. In the second case after the second AAA, Curie precisely states the affirmative version of the DNP which expresses the result of the AAA : "Le champ éléctrique [a pour] symétrie caractéristique celle du group (c)" (p. 404). His conclusion of the third AAA, the DNP "Le champ magnétique est donc seulement compatible avec le group (d) et ses intergroups" (p. 406), is not translated into an affirmative proposition ("Le champ magnétique a…"); however, a reader grasps exactly the meaning of the corresponding affirmative proposition thorough Curie's use of the enhancing word "seulement" in the latter proposition. In conclusion, Curie substantially applied three times the PSR, although two times in an implicit way.

In sum, Curie's paper presents three little theories, each substantially conforming to the model of a PO. Under this light, the first three "propositions", (p. 400) which are based on modal words (and which hence are DNPs), are to be considered as methodological principles to be applied to a inductive research for finding out a symmetry group.[8] Both following fourth and fifth "propositions" play a theoretical role which are apparent from their applications within the argumentations of respectively the second and third problems (pp. 404, 406); both are methodological principles addressing the new search for the resolution of the given problem.[9]

6. Speculations on the intellectual path of Curie

Let us recall that at the end of the paper Curie suggests theoretical "conclusions" generalizing at the highest possible theoretical levels the previous contents. Let us speculate upon Curie's intellectual path for achieving these metaphysical "conclusions" from his physical research.

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[6] Notice that the S4 model of modal logic is equivalent to the intuitionist logic (Hughes and Cresswell 1996, pp. 224 ff.). Hence, a modal word is equivalent to a DNP.

[7] Notice that in the past PSR was a considered a metaphysical principle leading to uncertain consequences. For this reason, it is not surprising that Curie does not mention it. According to a PO theory its translation of the final DNP of an AAA performs a trespassing from a hypothetical world, expressed by the DNPs, into the real world expressed by affirmative propositions; of course, this principle, based on the rationality of the world, it not enough for establishing this trespassing to reality. Markov (1971, p. 5) suggested that its correct application is assured when the predicate is subjected to two constraints: 1) to be derived from an AAA and 2) to be decidable. In the case of Curie's paper both constraints are clearly fulfilled.

[8] The use of DNPs for stating Curie's propositions persists also in Castellani (2000, pp. 67 and 71). Also in Rosen (1995, pp. 191-192) most of his many articulated versions of Curie's principle are DNPs.

[9] The paper includes also elementary arguments for proving that in a same medium the different dissymetries add (Sect. V), plus general considerations on the relative character of a symmetry with respect to a medium (Sect. VI). Instances of characteristic phenomena of the various examined symmetries are added in Sect.s IV-VI.

His basic task was to attribute a group to each of three physical fields. I suppose that, after having obtained the conclusions of three respective AAAs, he by induction generalized these conclusions into a single, general proposition: "No physical field without a specific group of symmetry". Furthermore, Curie was looking for an axiom principle of a theoretical framework that was more general than a single physical theory. Theoretical physicists of his time well-known the metaphysics of cause-effect in Newton's mechanics; therefore, in order to make acceptable his physical theory, Curie tried to model the wanted principle within a similar metaphysics.

The notion of "physical field" is now the "cause" and the specific group is the "effect". However, Newton's metaphysics suggested a translation of the notion of "cause" into a physical notion, "force", which then becomes a mathematical function of position and time. Instead, Curie's metaphysics is a defective one and moreover does not have an accurate translation into physical and mathematical notions. Hence, he only presented the verbal formulas of both the first two "propositions" and his "conclusions" which he formulated like to the celebrated, verbal formula of PSR. As a result, all his propositions have the same logical formula of the PSR ($\neg\exists x \neg r(x)$, where *r* stands for "reason").[10] But Curie jumped from the specific physical notions previously examined by him to the word "cause" in an unsupported way, because in some cases the causes are not determined.

In conclusion, Curie's introduction of a specific metaphysics of his set of symmetries has to be considered as a Curie's unsuccessful attempt of enhancing his physical theory at a level of metaphysics which is comparable with that of Newton's mechanics of his time and also Leibniz metaphysics of the PSR.

One more my hypothesis is that he perceived that, in order to make acceptable the results of his research by scientists' community of his time, he tried to model his theory according to an AO. However, being constrained to remain faithful to the inductive nature of his language, he also referred to the intuitionist arguing; in particular, he essentially relied on DNPs, AAAs and the application of the PSR. As a result, Curie's text mixed the two kinds of theoretical organization, an AO, partially prepared by a specific metaphysics, and a PO including all its components. This intricate mixture is a second reason why along one century and more the interpretation of his paper represented a great problem.

Appendix: The relevance of doubly negated propositions in theoretical physics and in Curie's text

Already in previous sect. 4, we remarked that many of Curie's propositions are modal and hence DNPs. It would be long to list all them. I confine myself to those of the two most significant parts of the paper: the introduction of his "propositions" and the final summary (For each DNP the corresponding affirmative proposition is added within square brackets in order to make easy to the reader to establish their inequivalence.

1. *La symétrie caractéristique d'un phénomène est la symétrie maxima compatible avec l'existence du phénomène.*
2. *Un phénomène peut exister dans un milieu qui possède sa symétrie caractéristique où celle d'un des intergroupes de sa symétrie caractéristiqu*e.
3. Autrement dit, certains éléments de symétrie peuvent coexister avec certains phénomènes,
4. mais ils ne sont pas nécessaires.
5. Ce qui est nécessaire, c'est que certains éléments de symétrie n'existent pas.
6. *C'est la dissymétrie qui crée* [= donne naissance de rien ≠ la symétrie implique] *le phénomène*.

[10] This connection was recognized by several scholars; e.g. Roche (1987, pp. 19-20). In the verbal version of PSR Leibniz refers to "reason", which is not a metaphysical word (although in some other versions of this principle he also refers to the word "cause"). Instead Curie refers to the word "cause": therefore, deliberately he is transcending to metaphysics. Moreover, Curie refers to the word "effects," which is an operational term; whereas Leibniz refers to the word "nothing" which is a metaphysical notion; unless it means "nothing belonging to a scientific research". In sum, whereas Leibniz's version of the PSR seems to avoid metaphysical words, Curie manifestly wants to refer to metaphysics through the word "cause".

> […] Here a long note on the preference between the dictions dissymmetries and symmetries].
> On peut encore voir que quand plusieurs phénomènes de natures différentes se superposent dans un même système, les dissymétries s'ajoutent.
> 7. Il ne reste plus alors comme éléments de symétrie dans le système que [≠ restent] ceux qui sont communs à chaque phénomène pris séparément.
> 8. *Lorsque certaines causes produisent certains effets, les éléments de symétrie des causes doivent se retrouver dans les effets produits.*
> 9. *Lorsque certains effets révèlent une certaine dissymétrie, cette dissymétrie doit se retrouver dans les causes qui lui ont donné naissance.*
> 10. La réciproque de ces deux propositions n'est pas vraie, au moins pratiquement, c'est-à-dire que les effets produits peuvent être plus symétriques que les causes.
> 11. Certaines causes de dissymétrie peuvent ne pas avoir d'action sur certains phénomènes ou du moins avoir une action trop faible pour être appréciée, ce qui revient pratiquement au même que si l'action n'existait pas (Curie 1894, p. 401).

Notice that the number of DNPs of this very short text is 11 and they summarize the logical thread of the discourse. Therefore a rhetorical use of the non-classical logic has to be excluded.

Let us now consider the "conclusions".

> *1) Il n'est pas d'effet sans causes* [≠ tous les effets ont de causes].
> 2) Les effets, ce sont les phénomènes qui nécessitent toujours [dérivent de], pour se produire, une certaine dissymétrie.
> 3) Si cette dissymétrie n'existe pas, le phénomène est impossible [≠ Si cette dissymétrie existe, il y a le phénomène].
> 4) Ceci nous empêche souvent de nous égarer à la recherche de phénomènes irréalisables [≠ adresse notre recherche].
> 5) Les considérations sur la symétrie nous permettent encore d'énoncer une deuxième sorte de conclusions, celles-ci de nature positive, mais qui n'offrent pas la même certitude dans les résultats que celles de nature négative [= offrent la même certitude dans les résultats que celles de nature positive].
> 6) *Il n'est pas de cause sans effets* [≠ toute cause a ses effets].
> 8) Les effets, ce sont les phénomènes qui peuvent naître [≠ naissent] dans un milieu possédant une certaine dissymétrie.
> 9) on n'a même qu'une [≠ on a une] idée imparfaite de leur nature exacte.
> 10) Cette dernière remarque montre qu'il faut se garder de tirer une conclusion absolue [= non relative] [≠ on tire une conclusion relative; i.e. physique] d'une expérience négative[11] (Curie 1894, p. 414).

It is remarkable that the set of these DNPs includes almost all the propositions of his summary. However, not all the above propositions are interesting: the no.s 2, 4, 5, 9, 10 do not refer to physical situations but to the rhetorical use of the double negations. However, the sequence of the remaining ones is meaningful; it substantially preserves the contents of Curie's illustration. This fact shows that Curie's use of DNPs is not a rhetorical one; rather it plays an essential role within the theory.

[11] Here the word "negative" negates something external to the sentence, it is purely indicative of a subject of the discourse; therefore, it should not be counted among the negations of the sentence.

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