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Plausible hypothesis constructed by abduction: some examples in sciences

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Abstract. The notion of abduction (with the meaning given by C. S. Peirce) is essential for the formation of new knowledge. However, it has not received enough attention from the philosophers of science. The abductive process runs in different domains of science. In astronomy, the discovery of movements of planets around the sun has been imagined by an abductive process, against Tycho Brahe's system. According to Georges Polya, abduction is also very important in mathematics, it is a creative in this field of sciences. In linguistics, it is by abductive inferences that Champollion discovered and understood the system of hieroglyphs of Egyptian old documents and that Ferdinand de Saussure discovered some phonemes of an (non observed and hypothetical) Indo-European Language.

The notion of abduction (or retroduction) introduced by C. S. Peirce (*Collected Papers*)[1], also defended by George Polya[2] under the name of "heuristic syllogism", is essential for the formation of new knowledge; however, it has not received enough attention from the philosophy of sciences; often misunderstood and misinterpreted, abduction has not acquired an adequate place in the study of the creativity in scientific activities. I have already underlined its importance in other papers[3], and I would like to give again some precisions about its role in scientific creativity.

1 Deduction, induction, abduction (retroduction)

Let us begin with a quotation by Peirce:

> There are in science three fundamentally different kinds of reasoning. Deduction (called by Aristotle συναγωγή or ἀναγωγή), induction (Aristotle's and Plato's ἐπαγωγή), Retroduction (Aristotle's ἀπαγωγή) but misunderstood because of corrupt text, and as misunderstood usually translated abduction. Besides these three, Analogy (Aristotle's παραγωγή) combines the characters of Induction and Retroduction. (Peirce, CP I, 65)

A simple example illustrates these three inference processes: Induction (I) is generalized by a law ("*All crows are black*") based on a correlation between observed facts ("*The crows that have been observed are all black*")

[1] [Peirce 1965] quoted by "CP" (for *Collected Papers*) in this article.
[2] [Polya 1965/1989: 106].
[3] [Desclés 1996]; [Desclés 2000].

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J.-P. Desclés, Plausible hypothesis constructed by abduction, pp. 55–72.

from a sample considered representative and large enough to be significant; Deduction (II) leads to a true statement (*This bird is black*) from two premises declared true ("*All crows are black*" and "*This bird is a crow*"); Abduction (III) (also called "retroduction" or "hypothesis" by Peirce) leads to the formulation of a plausible hypothesis ("*It is plausible that this bird is a crow*") based on the attested fact ("*This crow-sized bird is black*") and common knowledge ("*It is well known that crows are black*").

> Retroduction is the provisional adoption of a hypothesis, because every possible consequence of it is capable of experimental verification, so that the preserving application of the same method may be expected to reveal its disagreements with facts, if it does so disagree. (Peirce, CP I, 68)

> Abduction is the process of forming an explanatory hypothesis. It is the only logical operation which introduces any new idea; for induction does nothing but determine a value, and deduction merely evolves the necessary consequences of a pure hypothesis. (...) Deduction proves that something must be; Induction shows that something is actually operative; Abduction merely suggests that something may be. (Peirce, CP V, 171)

The different reasonings are compared with different inference schemes as follows:

Induction (I)	*Deduction (II)*	*Abduction (III)*
$\dfrac{a_1, \ldots, a_i, \ldots, a_n \quad P(a_i) \,\&\, Q(a_i) \quad (1 \leq i \leq n)}{(\forall x)[P(x) \Rightarrow Q(x)]}$	$\dfrac{P(a) \quad (\forall x)[P(x) \Rightarrow Q(x)]}{Q(a)}$	$\dfrac{Q(a) \quad (\forall x)[P(x) \Rightarrow Q(x)]}{\text{is-plausible } (P(a))}$
Induction shows that something is *actually operative.*	Deduction proves that something *must be.*	Abduction merely suggests that something *may be.*

Abduction is tantamount to imagining a plausible hypothesis intended to explain, with the help of an inferential process, certain facts, some may seem rather unexpected and *a priori* surprising. Inference by Abduction (III) is completely different with an inference by Induction (I) and it is not an inference by Deduction (II).

> Presumption [abduction] is the only kind of reasoning which supplies new ideas, the only kind which is, in this sense, synthetic. Induction is justified as a method which must in a long run lead up to the truth, and that, by a gradual modification of the actual conclusion. There is no such warrant for presumption. The hypothesis which it problematically concludes is frequently utterly wrong itself, and even method need not ever lead to the truth. (...) Its only justification is that its method is the only way in which there can be any hope of attaining a rational explanation. (Peirce, CP II, 777).

Inductive inference constructs *a general law* (i.e., an implication $[p \Rightarrow q]$ between two propositions) from *a set of correlations between different occurrences* 'p_i' of 'p' and different occurrences 'q_i' of 'q'. Following statistical considerations on correlations, the general law can take the following *probabilized form* $[p \Rightarrow \text{is probable } (q)]$, which allows to deduce the probability of a conclusion from a fact-finding. Deductive inference constructs a consequence 'q' of a general law $[p \Rightarrow q]$ when a hypothesis 'p' is considered as a true proposition. Adductive inference constructs a plausible hypothesis from *a general law* $[p \Rightarrow q]$ and *a true proposition* 'q' (e.g., an observed fact), and, in this case, 'q' is considered a consequence of the 'p' hypothesis. With abductive inference the proposition 'p' can be false when the premises 'q' and $[p \Rightarrow q]$ are true. In an abductive process, the proposition 'p' *is only a plausible explanation* of the fact 'q'; the explanation of the observed proposition (a statement) must be found; in this case, the proposition 'q' functions as a clue in favour of the plausibility of the hypothesis 'p'.

Remark: The inference scheme of abduction is very different from the inference scheme of deduction by *modus tollens*:

Deduction (*modus ponens*)	*Deduction* (*modus tollens*)	*Abduction*
p	$\neg(q)$ (negation of q)	q
$[p \Rightarrow q]$	$[p \Rightarrow q] = [\neg(q) \Rightarrow \neg(p)]$	$[p \Rightarrow q]$
q	$\neg(p)$ (negation of p)	is-plausible (p)

2 Abduction is a cognitive inference process

The process of inference by abduction that proposes a plausible hypothesis about the occurrence of an observed fact is a cognitive process, perhaps specific to human cognition. It is used in everyday life, for example from the observation "*Hey, the road is wet*" (proposition 'q'), we can infer, by an abduction, that "*It rained*", hence a statements like "*So, it rained*", that is to say the enunciation of a plausible proposition 'is plausible (p)', constructed from the general law "*When it rains, the road becomes wet*", which is a matter of common knowledge. However, other explanations can replace this plausible hypothesis, for example "*The municipal sprinkler passed by there a short time ago*" linked to common knowledge "*If the municipal sprinkler passes the road becomes wet*".

Let us present an example given by G. Polya[4]. As the three ships sailing West have not seen land (China or India) appear on the horizon as indicated in Christopher Columbus' plans, the crew was planning to revolt; however, some of its members noticed the presence of birds around the boats; this

[4] [Polya, 1958/2008: 181]; [Polya, 1965/1989: 104–108].

observation triggers abductive reasoning based on knowledge of sailors "*birds fly around the boats on land*" ($[p \Rightarrow q]$); since they have seen more and more frequent flights of birds around the ships ('q'), it was very plausible that one was near land ('is-plausible (p)'), they waited before beginning a revolt; indeed, the sailor on the lookout soon shouted "*Earth!, Earth on the horizon, in front of us!*". Thus, Christopher Columbus and his three ships were able to land a large island (the island of San Salvador) off the coast of this New World—not on the mainland of China or India as they believed—that will become America.

2.1 "Evidentiality" (or "mediativity") expressed by natural languages

The cognitive process of abduction reasoning is generally expressed by contextualized linguistic expressions. Many languages have grammatical systems to explicitly indicate by means of utterances specifying inferences by abduction; in these languages, the grammatical systems contain explicit grammatical morphemes grouped together under grammatical label of "evidentiality" (or "mediativity")[5]. The natural languages as Tuyuca, Tariana, Quechua, Kashaya[6] are examples of natural languages having an evidential system with more than one inferential morpheme depending on the type of inference; they use grammatical markers to express the enunciation of a plausible hypothesis from an abductive inference; the grammatical markers indicate to the co-enunciator that the enunciator has certain clues in favour of the plausibility expressed by the utterance; other natural languages do not express directly "evidentiality" by a system of specific grammatical markers but these languages can perfectly express this semantic notion. The clues in favour of a plausible hypothesis are not expressed in the enunciation of a plausible hypothesis but they can be specified when the reason for this plausible hypothesis is demanded; for instance:

– *Hey, it has rained.*

– *Why do you say that?*

– *Look! The road is wet* [it is a clue in favour of a plausible hypothesis].

Let us take the example of Panare, a Caribbean language of Venezuela with morphological mechanisms whereby speakers must specify whether the fact they are presenting has been personally verified, or whether it is a hypothesis based on observed clues and therefore simply plausible:[7]

[5] [Guentchéva 1996]; [Guentchéva & Landburu 2007]; [Desclés & Guentchéva 2018, 2024].

[6] [Barnes 1984] for Tuyuca; [Aikhenvald 2003] for Tariana; [Faller 2002] for Quechua; [Oswald 1986] for Kashaya.

[7] [Mattéi-Müller 2007].

(1) *a-të-**se*** *mën* *kanawa* *Ehkara* *pana*
Intr-go-PST:Imm Cop:Inan car Caicara DIR
'The car just left for Caicara.'

(2) *n-ti-**yah*** *kën*
3-go-PST:Rec 3Sg:An:NonVis
'It has left.' [The speaker saw it go]

(3) *yu-të-**hpë*** *mën* *kën*
3Intr-go-PERF:Infer Cop. 3Sg:An: NonVis
'It has left.' [herefore, it must have left]
[Description by the author: The speaker notes that the person's hammock is no longer there and infers that the person has left].

Thus, utterances (1) and (2) are distinct from (3). In (1), the verb form bears the suffix '***-se***', it indicates a declarative sentence referring to an empirically observed fact; (2) denotes the state resulting from the same observed fact; in (3), the speaker neither verbalizes the resultant state as in (2), nor the occurrence of a recent past event as in (1); in (3), relying on clues (for example the person's hammock which is no longer there) and shared knowledge (when you leave a place, you take your hammock with you), the enunciator expresses a hypothesis, deemed highly plausible, based on clues that the person has left. The grammatical marker '***-hpë***' is an evidential marker that expresses the result of an abductive inference. In different languages (as Albanian, Bulgarian, Farsi, Georgian, ...), the perfect has given rise to a series of perfect-like forms which can express abductive inference based on clues; this grammatical form is used by detectives to elucidate a crime by an abductive reasoning based on a set of observable clues (broken window, traces of blood or other indications), the most plausible hypothesis can be confirmed or infirmed by the discovery of new clues, as in Bulgarian (a southern Slavic language):

(4) *Kradecăt* *e* *vljazal* *v* *kuxnjata* *prez* *prozoreca*
thief.Art be.PRES enter.PAP.Pf in kitchen-ART through window.Art
'The thief has entered the kitchen through the window.'

One finds the same type of examples in the Nakh-Daghestanian languages, such as Agul, where judging from chips and other visible clues (scratches, ...) the speaker verbalizes a hypothesis to explain the observed facts.

The fact that natural languages express evidential (or mediative) statements, through explicit markers (sometimes grammaticalized in some languages), to indicate that the statement is based on abductive reasoning (with the recognition of clues and relationships established between plausible hypotheses and clues), leads us to think that the process of reasoning by abduction is a cognitive capacity, probably specific to humans, linguistic expressions being the observable traces of this capacity.

2.2 Abduction in everyday life

We are all faced with stating plausible hypotheses that can be explained, if we have to justify ourselves, by referring to clues:

- *Hey, a wild boar has passed by.*
- *Why?*
- *Well, look at these traces; they are the hoof traces of a wild boar.*

The hypothesis put forward as plausible can still be contested, or even completely refuted:

- *The boss has not arrived yet.*
- *Why?*
- *Look at his car. It is not in the parking lot.*
- *The boss's car is broken. Yesterday, he had to go back home by taxi.*
- *Thus, the boss, who usually arrives quite early at the office, would probably be already there.*

In the enunciation by an enunciator, called 'EGO', of a plausible (mediative or evidential) hypothesis, we have four steps:

1°) Observation of an observed fact 'C' (sometimes may be surprising);

2°) This observation triggers the search for a link between this fact 'C' and another fact 'H' which is likely to be an explanation of 'C';

3°) A reasoning by an adductive inference: '$C \,\&\, [H \Rightarrow C] \vdash$ is-plausible (H)';

4°) Enunciation of the plausible hypothesis: 'EGO-DIT (is-plausible (H))'.

The existence of certain historical figures (Napoleon, Jesus Christ, ...) is accepted as a plausible hypothesis, which can sometimes become hardly questionable since it derives its justification from more or less strong clues: Napoleon left material traces (his bicorn, a coat, letters, stories about his life and his actions, ...):

> Numberless documents and monuments refer to a conqueror called Napoleon Bonaparte. Though we have not seen the man, yet we cannot explain what we have seen, namely, all these documents and monuments, without supposing that he really existed (Peirce, CP, 2.625).

Some historians have questioned the existence of Jesus Christ because they have not found enough irrefutable clues, others, have been convinced in this existence based on strong clues (various converging narratives, indirect testimonies, consequences of this existence, ...). For instance the historian Jean-Christophe Petitfils considers, along with other historians, that the Healthy Shroud of Turin conjures up relevant facts in favour of the existence of Jesus Christ, while the philosopher Michel Onfray defends the idea that Jesus Christ has never existed, being a simple construction of the mind; this viewpoint is criticized by various historians[8]. This controversy shows that, relying on the same set of clues, several plausible hypotheses can be considered and discussed without necessarily leading to acceptance or rejection of "the best hypothesis". George Polya[9] noted that two people, confronted with the same argument and applying the same plausible inferences, may honestly find themselves in disagreement.

The paleontologist is led to state the plausible proposition: "*The sea was to cover these places in very ancient times*", following the discovery of fossils in the form of fish buried in the earth at the top of a hill, appealing to the general law: "*Fish live inside the seas*". Peirce writes:

> Fossils are found; say, remains like those of fishes, but far in the interior of the country. To explain the phenomenon, we suppose the sea once washed over this land. (Peirce, CP, 2.625)

2.3 Abduction and the reasoning by a detective, by a physician or by legal experts

Sherlock Holmes' plausible hypotheses are, in fact, abductive inferences as perfectly established by the semioticians Umberto Eco and Thomas A. Sebeok.[10] If we analyze Sherlock Holmes' method, we find out that what the detective (alongside with the author Conan Doyle) means when talking about Deduction and Observation, is, in fact, inference similar to Peirce's abduction. It is interesting to note that the above semioticians have compared the detective's reasoning to a physician's reasoning who seeks to observe the presence of certain symptoms to identify, as a result of abductive reasoning, a disease that would be the cause of these clues. In Umberto Eco's *Le Roman de la Rose*, Guillaume de Baskerville, in explaining the method followed, begins by discarding the idea of deduction as well as that of induction, and goes on to describe what Peirce calls abduction. In the domain of legal expertise, George Polya[11] gives excellent examples of heuristic inferences by abduction.

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[8] [Petitfils 2022]; [Onfray 2023].

[9] [Polya 1958/2008: 234].

[10] [Levesque 2016].

[11] [Polya 1958/2008: 171–181].

3 Fundamental properties of abduction

Some of observed facts may be "surprising" and inexplicable outside the forwarded hypothesis. The surprising facts fall under the name of *serendipity*[12]. In order to be explained, the phenomena called serendipity often lead to triggering reasoning by abduction in order to be explained. However, in an adductive inference, the findings that trigger this inference are not necessarily "surprising", they may be perfectly "normal". The explanatory hypothesis, however, remains simply plausible and may be opposed by other equally plausible hypotheses.

A plausible hypothesis can be rejected, it is the epistemological force of abduction; the hypothesis *that explains one or more facts is not a truth*, it is always refutable in particular following the fact '$\neg(C)$' (negation of 'C') which contradicts what must be "normally" deduced from this hypothesis; by following this negative observation, the hypothesis must be rejected:

$$[H \Rightarrow C] \mathbin{\&} \neg(C) \vdash \neg(H).$$

In some cases, the assumption may be modified and adjusted to take into account this negative fact.

A plausible hypothesis can be justified and reinforced by a bundle of concordant clues. The abductive scheme of inference becomes:

$$[H \Rightarrow (C_1 \mathbin{\&} C_2 \mathbin{\&} \ldots \mathbin{\&} C_n)] \mathbin{\&} (C_1 \mathbin{\&} C_2 \mathbin{\&} \ldots \mathbin{\&} C_n) \vdash \text{is-plausible } (H).$$

The bundle of observed clues '$C_1 \mathbin{\&} C_2 \mathbin{\&} \ldots \mathbin{\&} C_n$' reinforces the plausibility of the explanatory hypothesis. For instance, the observations that the orbits of different planets are ellipses reinforce the plausibility of the Copernicus' heliocentric system.

Several plausible hypotheses 'H_1' and 'H_2' can often co-exist; both 'H_1' and 'H_2' hypotheses can explain the same facts:

$$C \mathbin{\&} [H_1 \Rightarrow C] \vdash \text{is-plausible } (H_1),$$
$$C \mathbin{\&} [H_2 \Rightarrow C] \vdash \text{is-plausible } (H_2).$$

As long as one does not discover facts that allow rejecting one of the hypotheses, both hypotheses must be *a priori* accepted as plausible. Thus, for a lot of philosophers, theologians, astrologers, during several years, the geocentric system co-exited with the heliocentric system; the two systems explained the same observations (but by different ways). We have seen above that the examination of the real existence of Jesus Christ leads to two plausible hypotheses that prove incompatible when taking into account the same clues provided by historical documents. Polya[13] evokes a discussion

[12] [Andel & Bourcier 2009].
[13] [Polya 1958 / 2008: 233–234].

about the value of a plausible hypothesis in mathematics and he notes that two people, confronted with the same argument, applying the same schemes of plausible inference, may in all honesty find themselves in a disagreement.

4 What abduction is not

Plausible hypothesis built by abduction is not (necessarily) "the best hypothesis"; some philosophers of science defend this feature of abduction[14]. For us, this is not admissible since several plausible hypotheses may explain the same observed facts but other considerations must also be forwarded to prefer a hypothesis and to reject another. When several plausible hypotheses are in competition, some researchers might prefer one hypothesis for simplicity reasons, ability to explain many other facts, and even aesthetics to satisfy the Ockam's razor. For instance, Copernicus' heliocentric hypothesis is much simpler than Tycho-Brahe's geocentric system, which must use many epicycles to account for the many observations, and the Copernican system, defended by Galileo, enabled to define laws that took mathematical forms and later lead to Newtonian laws.

It is essential not to confuse on one hand, *the enunciation of a probable consequence of a fact* and on the other hand, *the enunciation of the plausibility of a hypothesis from an observed fact* interpreted as a clue. Indeed, the contexts of these two enunciations are often entirely different. Let's take two different contexts. Context I: this morning, people discover corpses on the beach (an observed fact 'q') and it is shared knowledge that when there is a shipwreck, corpses always wash up on the beach; thus one person can say: "*Therefore, there must have been a shipwreck the other night*"; 'is-plausible (p)' is inferred by reasoning by abduction from the clue 'q'. Context II: there was a shipwreck during the night (it is a fact 'p') and this morning, one people can say: "*There will probably be corpses on the beach*"; 'is-probable (q)' is a consequence of 'p' because it is common knowledge that when there is a shipwreck in the vicinity, the corpses of the castaways often wash up on the beach (the implication [$p \Rightarrow$ probability (q)] is common knowledge). To give an example of this difference let us take Pomo language where Robert Oswalt isolates two suffixes '***-qă***' and '***-bi***' in his grammar of Kashaya[15]; he distinguishes (5a) from (5b) with two different interpretations, but, unfortunately, with a same translation in English:

(5) a. *sinam**q**ʰ*
drown-INFER.I
'He must have drowned'

b. *sinamqˀ**bi**w*
drown: INFER II: ABS
'He must have drowned'

[14] [Walton 2004] for instance.
[15] [Oswalt 1961: 243].

of the two inference schemes relative to context I (with a plausible hypothesis) and context II (with a probable consequence):

Context I: q (constat) & $[p \Rightarrow q] \vdash$ is-plausible (p);

Context II: p (constat) & $[p \Rightarrow$ is-probable $(q)] \vdash$ is-probable (q).

in Kashaya, when a person enters a house and detects the smell of baked bread, he could say either (6) or (7):

(6) *cuhni·* *muˀ'ta-**q**ʰ*
bread cook-INFER.I
'Bread has been cooked'

(7) *cuhni·* *muˀ'ta* *mihšew*
bread cook smell
'It smells like cooked bread'

In sentence (6), the smell is a clue, hence the inference of a highly plausible hypothesis: "bread has been cooked". In contrast, in (7), there is no inference and the verb is used simply to declare a direct olfactory perception.

5 How to check the accuracy of an abduction?

The formulation of a plausible hypothesis from a reasoning by abduction leads quite naturally reinforcing the plausibility of the hypothesis by resorting to statistical correlations between the hypothesis and the occurrences of observed cases, so as to be able to pose the general law: $[H \Rightarrow C]$. Here, the induction which concludes with the formulation of a general law is guided by the hypothesis 'H' that should be confirmed or rejected when the number of proven correlations (the sample) is considered too low. When the inductive test is positive, the reasoning by abduction takes the form: C & $[H \Rightarrow C] \vdash$ is-plausible (H); in this case, the plausible hypothesis 'H' can be accepted (at least provisionally) as an acceptable scientific hypothesis (therefore assumed to be true) which becomes an explanation of the observed case 'C'.

> The induction adds nothing. At the very most it corrects the value of a ratio or slightly modifies a hypothesis in a way which had already been contemplated as possible. (Peirce, CP VII, 217)

> For abduction commits us to nothing. It merely causes a hypothesis to be set down upon our docket of cases to be tried. (Peirce, CP V, 602)

> [. . .] the entire meaning of a hypothesis lies in its conditional experiential predictions: if all its predictions are true, the hypothesis is wholly true. (Peirce, CP VII, 203)

Abduction can sometimes lead to dead ends. The study of anagrams by Ferdinand de Saussure is a very good example; in the latter part of his life, Saussure became passionate about the study of anagrams, trying to discover hidden hypotheses, a kind of "occult traditions" in Greek and Latin poetry[16]; he first proposed hypotheses and then complicated them by other hypotheses. The inductive verifications led him to find out that there were practically no restrictions (no laws) all the constructions examined could support the hypothesis put forward on the anagrams. He gave up this research.

6 Examples of discoveries from reasoning by abduction

Let us quote different examples of formulations of plausible hypotheses in different domains of sciences (natural and human sciences).

6.1 Plausible hypotheses in mathematics and astronomy

In the field of mathematics, the reasoning by abduction (under the name of "heuristic reasoning") is the discovery and formulation of a new plausible proposition that must then be demonstrated to make a mathematical truth. For example, the Fermat's conjecture (for $n > 2$: $[a^n + b^n = c^n]$ is impossible), is a plausible hypothesis whose justification can be based on a large number of consequences demonstrated as true; these demonstrated consequences confirm the plausibility of the conjecture but they are not a proof; despite many efforts, Fermat's conjecture has not been demonstrated for three centuries, but, finally, Andrew Wiles, in 1993, has given a proof, which after many verifications, has been accepted by the community of mathematicians[17]. At present, the Riemann's conjecture, which aims to shed light on the infinite distribution of prime numbers, has not been proved yet.

In the field of astronomy, Polya[18] traces Kepler's different hypotheses and rejects them. Kepler seeks to discover the cause or some reason for the number of planets, their distance from the sun and the periods of their revolutions; he imagines 11 concentric surfaces, 6 spheres alternating with 5 regular polyhedra. The first surface is external to the others, it is a sphere and each surface is encompassed by the previous one; to each sphere is associated a planet, the radius of the sphere gives the (average) distance of the planet to the sun. Each polyhedre is inscribed in the previous sphere and is circumscribed to the next sphere. Kepler compares the plausible hypothesis with observations. The expected agreements are good in some cases and very bad in others. Kepler must therefore modify his initial hypothesis while remaining faithful to his preconceived idea: the sphere is the "perfect figure" and the five regular polyhedra, the figures of Plato,

[16] [Starobinnski, 1971]; [Fadda 2018: 25–28].
[17] [Hellegouarch, 1997]; [Singh 1998].
[18] [Polya 1958/2008: 137–140].

are the "noblest figures". It therefore seems "natural" to him that the sun and the planets are in a certain way linked to the figures of Euclid. Polya notes that the confidence we place in a hypothesis depends on the cultural environment and the scientific atmosphere of a period; he also emphasizes Galileo's intellectual courage and his independence of mind facing prejudice of his time while Kepler, a contemporary of Galileo, was influenced by the mysticism and the prejudices of his time.

6.2 Non-observable plausible hypotheses in relation to observables in physics

We can quote several examples of plausible hypotheses proposed by researchers without direct observable correspondents. These assumptions can then slightly to be adjusted and finally accepted, for example from the results of new observations, or they may be heavily modified and sometimes rejected. Jean Perrin formulated the atomic hypothesis of atoms (with protons with electrons around). Criticized in the beginning, this hypothesis has finally been accepted by the entire community before being seriously refined by contemporary physics. Albert Einstein, who defended, for *a priori* ideological reasons, the hypothesis of a homogeneous isotopic Universe, preferred to modify the equations of General Relativity by introducing a "cosmological constant" that preserved the stability of the Universe. Faced with a large number of empirical results, Einstein will recognize his error ("*the greatest mistake of my life*") and return to this cosmological constant by accepting the hypothesis of a dynamic Universe that expands (or contracts).

Drawing certain consequences from Einstein's General Relativity, the physicist Georges Lemaître formulated in 1927, after Alexander Friedmann (1922), the hypothesis of the "primitive atom", which assumed a temporal beginning of the Universe, that is to say the hypothesis of the "Big Bang" highlighted by Edwin Huggle in 1929. This hypothesis was opposed to the idea of a stable and eternal Universe, commonly accepted at this time. The discovery in 1965 by Arno Penzias and Robert Wilson of an "echo" of a cosmic microwave background confirmed the dynamic cosmological scenario of a rapid expansion of the Universe from an extremely dense and extremely hot state. This Big Bang hypothesis has given rise to many philosophical interpretations. The Big Bang hypothesis is now accepted as plausible but not in the form of "a primitive atom", extremely dense and hot, which would have exploded and separated on one side a nothingness and on the other hand, a world where time and space took shape. The plausible hypothesis of the Big Bang leads to the formulation of many scientific and philosophical problems that do not yet find real answers.

In the field of quantum physics, confronted with the phenomena of interactions at the atomic and subatomic level, it is necessary to formulate many plausible hypotheses at the source of mathematical calculations that account for experimental results but as Richard Feynman[19] says, we are not really sure that we have yet really "understood" the world of quantas.

6.3 Two examples of a discovery of a plausible hypothesis in linguistics

The two following examples, borrowed from linguistics, clearly show that there are scientific approaches in the human sciences, as in the natural sciences, which lead to very solid results capable of garnering the support of specialists in the discipline.

Jean-François Champollion (1822) has been able to justify his plausible hypothesis following a succession of more or less refined hypotheses and the rejection of false hypotheses. Having had access to new documents (the Huyot documents), Champollion decided to apply the writing system used for the names of Greek kings to the names of the rulers of the high Egyptian Empire. By analyzing new names, he formulated the hypothesis of the triple writing system of Egyptian hieroglyphics, which are, for some, phonetic inscriptions, for others, ideographic and also symbolic inscriptions[20]. Before the formulation of this fruitful hypothesis, for many years, Champollion, following Sylvester de Sacy, defended the exclusively ideographic nature of Egyptian hieroglyphics, and he persisted in believing that this was a self-evident fact until the evidence of the facts led him to recognize the phonetic value of a group of hieroglyphics constituting the inscriptions that decorated Egyptian monuments of different periods. The adductive approach undertaken by Champollion allowed to obtain solid results that the method of its competitor Thomas Young could not achieve.

The young Ferdinand de Saussure (1879) formulates an plausible hypothesis about the proto-Indo-European language. There are three major periods in Ferdinand de Saussure's work: (i) the period of youth with the publication of the *Mémoire* (called *Le Système primitif des Voyelles dans les langues Indo-européennes*) presented in Leipzig in 1879, which made him noticed among the linguists of this time; (ii) the period of the courses professed at the University of Geneva with the publication of the famous *Cours de Linguistique générale* (written by three of the course's auditors), which earned Saussure to be considered one of the great founders of structural linguistics and general linguistics; (iii) the period of research on the anagrams (mentioned above). It is the first period, that of the *Mémoire*, which interests us here. By examining the systems of vowel alternations in several known languages (Greek, Sanskrit, Latin, Germanic languages, ...) and based on general rules of diachronic changes formulated by different linguists, Saussure, only 21 years old, formulates this hypothesis: "A cer-

[19] [Feynman 1965].
[20] [Lacouture 1988]; [Desclés 2000: 97–99].

tain phoneme, not attested in the languages studied (of the Indo-European family), exists in the proto-Indo-European language; this phoneme would make it possible to explain all the phenomena attested in all the studied languages of this family of languages". This phoneme is a laryngal that Saussure calls 'coefficient sounding'; this reconstructed phoneme is absent in all the languages hitherto observed but its plausible existence made it possible to explain some embarrassing phenomena. The plausibility of this hypothesis is based on laws of phonetic change formulated, at this time, by the works about the comparison of studied indo-european languages. The Saussure's hypothesis makes it possible to link this phoneme, not empirically directly observed, to a certain number of phonemes that are attested in different studied indo-European languages. It was only in 1927, after the deciphering of the Hittite language by F. Kurilowicz, that was actually observed a phoneme which Saussure's reasoning had put in place in the form of a plausible hypothesis about a proto-Indo-European language[21].

6.4 Semantic representations related to linguistic expressions

Nowadays, cognitive linguistics uses semantic-cognitive representations—unobservable—that have grammatical markers (tenses, aspects, various modalities, determination) as observable traces in the semiotic systems of natural languages. The lexical units of verbs and prepositions have meanings that are described precisely by more abstract cognitive representations, obtained by composing cognitive "primitives" closely related to perception, action and agents with more or less intentional aims, in nested and entangled relationships. The linguist Sebastian Shaumyan[22], taking up a distinction of a biological nature between genotype and the various phenotypes, undertook the description of the Grammar of a genotype language—not accessible to direct observation—with two levels of description: on the one hand, the linguist must describe the main invariant constructions of language activity; on the other hand, he must link these invariants to the different observed phenotype languages, semiotic systems organized by the specific rules of these natural languages. Let us take an example: by differentiating according to the order of grammatical and lexical units in standard sentences, some natural languages (Ancient Greek, Latin, Arabic, ...) grammaticalize explicitly certain constructions with mandatory morphological cases but not other languages (as English, French, ...). The two models, 'Applicative and Cognitive Grammar' (GAC) and 'Applicative, Cognitive and Enonciative Grammar' (GRACE)[23], develop Shaumyan's ideas, by linking plausible semantic-cognitive representations, not directly observable, to the observable semiotic forms of natural languages, by means of intermediary changes of

[21] [Apresjan 1973: 98–101]; [Desclés 2000: 99–102].
[22] [Shaumyan 1977, 1987].
[23] [Desclés 1990]; [Desclés et al., 2016].

representations expressed by inferences formulated in the formalism of the Combinatory Logic of Curry[24], a logic of whatever operators intrinsically combined and transformed by abstract operators, called "combinators" (according to a general hypothesis of compiling between different levels of representations)[25].

7 Conclusions

In conclusion, let's listen again to Peirce:

> Abduction is the process of forming an explanatory hypothesis. It is the only logical operation which introduces any new idea; for induction does nothing but determine a value, and deduction merely evolves the necessary consequences of a pure hypothesis. Deduction proves that something must be; Induction shows that something is actually operative; Abduction merely suggests that something may be. (Peirce, CP V, 171)
>
> Presumption [abduction] is the only kind of reasoning which supplies new ideas, the only kind which is, in this sense, synthetic. Induction is justified as a method which must in a long run lead up to the truth, and that, by a gradual modification of the actual conclusion. There is no such warrant for presumption. The hypothesis which it problematically concludes is frequently utterly wrong itself, and even method need not ever lead to the truth. (...) Its only justification is that its method is the only way in which there can be any hope of attaining a rational explanation. (Peirce, CP II, 777)

From what we have just recalled in this article, it becomes clear that the formulation of a creative hypothesis does not emerge from big data. The creative hypothesis aiming to "explain" a problem or some questions that a researcher has been able to discover and to formulate this hypothesis in precise terms, is often adductive: 1°) he observes problematic facts that are not explained (sometimes surprising and going against common knowledge); 2°) to explain these facts, he formulates a new hypothesis 'H' which maintains relations of implication with these problematic facts, this is the important moment of explanatory creativity; 3°) he infers, by a reasoning by abduction, that the hypothesis 'H' is plausible; 4°) this hypothesis 'H' would thus explain (at least provisionally) the nature of the problem raised by finding the observed problematic facts. Thus, the researcher and his community (scientific, cultural, social community etc.) should seek to strengthen the plausibility of the hypothesis stated, by examining the consequences of the hypothesis or, sometimes, by accepting that this hypothesis, supported as only plausible and therefore fallible, must ultimately be rejected or, in

[24] [Curry et al. 1958, 1972].

[25] [Desclés 2004]; [Desclés et al. 2016].

some cases, must be entirely reformulated to fit more accurately to the consequences of the plausible hypothesis. The accumulation of data rarely leads to the formulation of a new hypothesis capable of explaining and understanding a certain number of problems that informed and attentive minds have been able to identify; on the other hand, the accumulated data are an adequate place where a plausible hypothesis can be confirmed or rejected.

References

[Aikhenvald 2003] Aikhenvald, Alexandra (2003). *A Grammar of Tariana, from Northwest Amazonian*, Cambridge: Cambridge University Press.

[Andel & Bourcier 2009] van Andel, Pek & Bourcier, Danièle (2009). *De la sérendipité dans la science, la technique, l'art et le droit*, ACT MEM.

[Apresjan 1973] Apresjan, Juri Derenikowitsch (1973). *Éléments sur les idées et les méthodes de la linguistique structurale contemporaine*, Paris: Dunod.

[Barnes 1984] Barnes, Janet (1984). *Evidentials in Tuyuca Verbs*, IJAL 50, pp. 255–271.

[Curry et al. 1958] Curry, Haskell & Feys, Robert (1958). *Combinatory Logic*, Vol. I, Amsterdam: North Holland Publishing.

[Curry et al. 1972] Curry, Haskell, Hindley, J. Roger, & Seldin, Jonathan P. (1972). *Combinatory Logic*, Vol. II, Amsterdam: North Holland Publishing.

[Desclés 1990] Desclés, Jean-Pierre (1990). *Langage applicatifs, langues naturelles et cognition*, Paris: Hermès.

[Desclés, 1996] Desclés, Jean-Pierre (1996). L'abduction, procédé d'explication en linguistique, *Modèles linguistiques*, Tome XVII, Fascicule 2, pp. 33–62.

[Desclés 2000] Desclés, Jean-Pierre (2000). *Abduction and non-observability. Some Examples from Language and Cognitive Sciences*, in Evandro Agazzi and Massimo Pauri (eds) 2000. *The Reality of the Unobservable*, Dordrecht: Springer, pp. 87–112.

[Desclés 2004] Desclés, Jean-Pierre (2004). *Combinatory Logic, Language, and Cognitive Representations*, in Weingartner (ed.) 2004. *Alternative Logics. Do Sciences Need Them?* Berlin: Springer, pp. 115–148.

[Desclés et al. 2016] Desclés, Jean-Pierre, Guibert, Gaëll, & Sauzay, Benoît (2016). *Logique combinatoire et lambda-calcul: des logiques d'opérateurs* (volume I); *Calculs de significations par une logique d'opérateurs* (volume II), Toulouse: Cépadues.

[Desclés & Guentchéva 2018] Desclés, Jean-Pierre & Guentchéva, Zlatka (2018). *Inference processes expressed by languages: Deduction of a probable consequent vs. abduction*, in Arigue & Rocq-Miguette (2018). *Theorization and Representations in Linguistics*, Cambridge Scholars Publishing, pp. 241–265.

[Desclés & Guentchéva 2024] Desclés, Jean-Pierre & Guentchéva, Zlatka (2024). *Évidentialité, médiativité, modalité épistémique, une approche énonciative, Conférence au Congrès Mondial de Linguistique Française*, CMLF 2024, Lausanne, 4 July 2024.

[Fadda 2018] Fadda, Emanuele (2018). *Abduction et firstness: la réalité du possible et la possibilité du réel*, in Clot-Goudard, Remi, et al. (eds; 2018). *Abduction, Recherches sur la philosophie et le langage.*

[Faller 2002] Faller, Martina (2002). *Semantics and Pragmatics of Evidential in Cuzco Quechua*, PhD Thesis, Stanford University.

[Feynman 1965] Feynman, Richard P. (1965). *The Feynman Lectures on Physics*, California Institute of Technology: Addison-Wesley Publishing Company, inc Reading, Massachussetts.

[Guentchéva 1996] Guentchéva, Zlatka (ed.; 1996). *L'énonciation médiatisée*, Paris-Louvain: Peeters.

[Guentchéva & Landaburu 2007] Guentchéva, Zlatka & Landaburu, Jon (eds.; 2007). *L'Enonciation médiatisée II: Le traitement épistémologique de l'information: Illustrations amérindiennes et caucasiennes.* Paris: Peeters.

[Hellegouarch, 1997] Hellegouarch, Yves (1997). *Invitation aux mathématiques de Fermat-Wiles*, Paris: Masson.

[Lacouture 1988] Lacouture, Jean (1988). *Champollion, une vie de lumière*, Edition Grasset et Fasquelle.

[Levesque 2016] Levesque, Simon (2016). Le Signe des Trois. Dupin, Holmes, Peirce d'Umberto Eco and Thomas Sebeok, *Cygne noir* 4.

[Mattéi-Müller 2007] Mattéi-Müller, Marie-Claude (2007). Voir et savoir en panaré (langue caribe du Venezuela), in [Guentchéva & Landaburu 2007: 153–169].

[Onfray 2023] Onfray, Michel (2023). *Théorie de Jésus*, Paris: Le Bouquin.

[Oswald 1961] Oswald, Robert (1961). *A Kasheya grammar (Southwestern Pomo)*, PhD Thesis, University of California at Berkeley.

[Oswald 1986] Oswald, Robert (1986). The evidential system of Kashaya, in Chafe & Nichols (eds; 1986). *Evidentiality. The Linguistic Coding of Epistemology*, Norwood N.J.: Ablex, pp. 29–45.

[Peirce 1965] Peirce, Charles Sanders (1965). *Collected Papers of Charles Sander Peirce*, Vol. I–VI, edited by Charles Hartshorne and Paul Weiss, Cambridge, Massachusetts: The Belknap Press of Harvard University Press.

[Petitfils 2022] Petitfils, Jean-Christophe (2022). *Le Saint Suaire de Turin Témoin de la Passion de Jésus Christ*, Paris: Editions Tallandier.

[Polya 1958/2008] Polya, Georges (1958). *Les mathématiques et le raisonnement plausible*, Paris: Gauthier-Villars; new edition: 2008. Paris: éditions Jacques Gabay.

[Polya 1965/1989] Polya, Georges (1965). *Comment poser et résoudre un problème, Mathématiques – Physique – Jeux – Philosophie*, Paris: Dunod; new edition 1989. Paris: éditions Jacques Gabay.

[Shaumyan 1977] Shaumyan, Sebastian K. (1977). *Applicational Grammar as a Semantic Theory of Natural Language*, Chicago: Chicago University Press.

[Shaumyan 1987] Shaumyan, Sebastian K. (1977). *A Semiotic Theory of Language*, Bloomington and Indianapolis: Indiana University Press.

[Singh 1998] Singh, Simon (1998). *Le dernier théorème de Fermat*, Paris: JC Lattès.

[Starobinnski 1971] Starobinnski, Jean (1971). *Les mots sous les mots. Les anagrammes de Ferdinand de Saussure*, Paris: Gallimard.

[Walton 2004] Walton, Douglas N. (2004). *Adductive Reasoning*, Tuscaloosa: The University of Alabama Press.