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The Deep Black Sea: Observability and Modality Afloat

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Abstract

In the spirit of B.C. van Fraassen's view of science called *Constructive Empiricism*, we propose a rigorous criterion to decide whether a concrete object is *observable*, and provide a rigorous account of modal language occurring in science, including subjunctive conditionals. We claim that our criterion of observability and our truth-conditions of 'subjunctive observation conditionals' solve *three* problems which current accounts of observability, notably Van Fraassen's own accounts, give rise to and hence do not solve. We also claim that our account of modality, which is supposed to be a rigorous version of Van Fraassen's own sketchy account, makes true his claim that such an account is possible without relying on 'inflationary metaphysics', such as positing an infinitude of worlds besides the one we live in. We thus claim to solve a *fourth* problem: how to give a non-realist, nominalist and precise account of modal language in science.

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1 Introduction: Rough Guides

Preamble. In this Introduction we set the stage of this paper by reviewing a recent dialectic which is taking place in this journal on the stage of B.C. van Fraassen's epoch-making and passionately debated view of science called *Constructive Empiricism* (CE), a view propounded in Fraassen [1980] and [1985]. The subject of the dialectic is the connexion between the concepts of *observability* and *modality*.[1] Within the confines of CE, their connexion stands in urgent need of attention, because J. Ladyman [2000: 855] perceived a tension between observability and modality so strong that it renders CE "untenable as a philosophy of science". When our brief review of the recent dialectic we are about to provide is finished, we present, at the end of this Introduction, a preview of this paper and a statement of what it hopes to contribute to the extant literature.

The Rough Guide. The two distinctions between (I) *observable* and *unobservable* concrete objects, and between (II) *extensional* and *intensional*, in particular *modal*, language in science are of crucial importance for the realism-debate.[2] This is because whereas Realists defend that scientific knowledge includes besides knowledge of actual *observables* also knowledge of actual *unobservables* such as viruses, atoms, black holes and electromagnetic fields, Anti-Realists beg to disagree; and because whereas most if not all Realists defend that scientific knowledge includes besides knowledge of what is *actual* also knowledge about what is *possible*, what is *contingent*, what is *necessary* and of what *would* happen if so-and-so *were* the case, Anti-Realists, again, beg to disagree as soon as these modal notions are supposed to be more than utterances *flatus vocis*. CE assumes a neutral epistemic attitude with regard to whatever science tells us about objects that are not actual or not observable; for CE, *scientific knowledge* is exclusively about actual observables.[3] Although distinct, distinctions I and II seem tightly connected, because surely we have the following logical equivalences: a DNA-molecule is unobservable iff it is *impossible* to observe it, and a living Tyrannosaurus is observable iff any person *would* see the creature if he *were* to stand in front of it in broad daylight with his eyes wide open. Therefore, either the concept of observability and modal concepts are all *epistemic* or they are all *pragmatic*.[4] This means that a view of science like CE suffers from a tension, because

[1] Besides propositions that include the familiar modal notions of possibility, contingency and necessity, we also count subjunctive conditionals among modal propositions. Like Quine, we take *propositions* to be classes of logically equivalent *statements* (declarative sentences); then every two statements which belong to the same proposition are either both true or both false — or both indeterminate if *tertium datur*. For the sake of convenience, we confuse 'statement' and 'proposition' at will.

[2] All *abstract objects*, such as concepts and mathematical objects, are by default unobservable. In this paper, *object* always means 'concrete (= non-abstract) object' unless specifically stated otherwise. Nothing in this paper depends on taking the distinction between concrete and abstract objects to be sharp or vague.

[3] Fraassen [1980: 7-12, 17, 72], [1989: 68, 202]. So the non-realism of CE is of the ontological and by implication of the epistemic kind with respect to both observables and modalities; cf. Niinniluoto [1999: 3].

[4] By 'epistemic' we mean here that the concept is always involved in deciding whether a given proposition of an accepted scientific theory counts as *scientific knowledge*, and by '(purely) pragmatic' when it is not always (never) involved in this. The concept of an explanation and of an inference-to-the-best-explanation

CE needs observability to be an epistemic notion whereas CE considers modalities to be pragmatic notions (Ladyman [2000] delves deeply into this tension).

The perceived tension, however, is not real. CE is not in trouble. Appearances deceive. The observability of object X is *not* a modal concept, it is *not* to be construed as '*the possibility* to observe X', but as '*our ability* to observe X'. By making this *slightly* revisionary move with respect to the vulgar tongue, as Bacon would say, one can consistently maintain that obervability is epistemic and all modal concepts are not. Van Fraassen ([1980: 17], cf. [1985: 252-258]):

> The human organism is, from the point of view of physics, a certain kind of measuring apparatus. As such it has certain inherent limitations — which will be described in detail in the final physics and biology. It is these limitations to which the 'able' in 'observable' refers: our limitations *qua* human beings.

Like breakable, inflammable, portable and consumable, observable is an *objective* dispositional property; like breakable and portable but unlike inflammable and consumable, observable is *vague*; and unlike breakable and inflammable but like portable and consumable, observable is *anthropomorphic* in that some object is observable-*to-us*, just like some object is portable-*by-us* or consumable-*by-us*. This means that observability is a *relation* between concrete objects and what Van Fraassen has called an 'epistemic community', which currently consists of all human beings with healthy eyes and healthy and unclouded minds (cf. Fraassen [1980: 18-19], [1985: 253-258]). What 'healthy eyes' are is a medical problem, and what a 'healthy mind' is, is a psychiatric problem; these problems are not philosophical problems: we gladly accept here what the doctors say. The phrase 'unclouded mind' is an umbrella-term for being sober, not under the influence of drugs, and what have you. Borderline cases, whose existence would testify for the vagueness of the term 'epistemic community' (not for its meaninglessness), should not be given membership of $\mathcal{E}$; in this fashion we play things safe.

Van Fraassen [1980: 16] provides nothing less than a principle formulated in extensional language to tell us what is observable (our **bold face**):

> The principle is: X is *observable* if there are circumstances which are such that, if X is present to us under those circumstances, then we observe X. This is not meant as a definition, but only as a **Rough Guide** to the avoidance of fallacies.

Hopefully this sufficient condition for observability is also meant as a necessary one, otherwise we could never decide when something is *unobservable* — Van Fraassen talks about unobservables all over the place. Let $\mathrm{Obs}(X, \mathcal{E})$ abbreviate 'concrete object X is observable with the naked eye of member p of the epistemic community $\mathcal{E}$'; let $\mathrm{Front}(p, X)$, where $p \in \mathcal{E}$, abbreviate 'p is at rest with respect to X, and is in front of X with his healthy eyes wide open and light is present, comparable in magnitude to broad daylight'; and let

are examples of pragmatic concepts according to CE, whereas the concept of a phenomenon, of truth and of empirical adequacy are epistemic.

$\text{Sees}(p, X)$ abbreviate 'p sees X veridically'.[5] Then we can abbreviate the Rough Guide as follows:

$$\text{Obs}(X, \mathcal{E}) \ \text{ iff } \ \forall\, p \in \mathcal{E} \,\big(\, \text{Front}(p, X) \ \longrightarrow \ \text{Sees}(p, X)\,\big)\ . \tag{1}$$

We call conditionals like the one between brackets to the right of 'iff' in (1) *indicative observation conditionals*, or *io-conditionals* for brevity. Rough Guide (1), however, does not avoid fallacies, as Van Fraassen meant it to. On the contrary, it invites a fatal fallacy.

Consider electrons on some planet in some galaxy far far away, or in the center of the Earth, places where no member of $\mathcal{E}$ is ever present. Consider microbes that live near the bottom of the ocean, areas the size of countries in the deep black see where no man has ever been and no ray of light has ever entered. Then the antecedent $\text{Front}(p, X)$ of Rough Guide (1) is always False, the io-conditional is True and we must conclude that these electrons and microbes are *observable*.[6] This, surely, is a *reductio ad falsum* of the Rough Guide (1).

The New Rough Guide. The general problem with Rough Guide (1) is that the io-conditional renders a single object *observable* as long as no one was ever near it; such objects virtually exhaust all objects in the universe. Monton & Van Fraassen [2003: 409] provide, following Ladyman [2000: 184], a way out: "The natural way to read it is a *counterfactual*." Call this the

> **New Rough Guide.** Concrete object X is *observable* iff there are circumstances which are such that, if X *were* present to us under those circumstances, then we *would* observe X.

With the standard abbreviation ($\Box\!\!\rightarrow$) for a subjunctive conditional (a *counterfactual* is a subjunctive conditional with a False antecedent, which is usually the case when one is asserted), we can abbreviate the New Rough Guide as follows:

$$\text{Obs}(X, \mathcal{E}) \ \text{ iff } \ \forall\, p \in \mathcal{E} \,\big(\, \text{Front}(p, X) \ \Box\!\!\rightarrow \ \text{Sees}(p, X)\,\big)\ . \tag{2}$$

We call conditionals like the one between the brackets to the right of 'iff' in (2) *subjunctive observation conditionals*, or *so-conditionals* for brevity. We keep calling them this if the antecedent or the consequent, or both, have a negation-sign in front of it. And *mutatis mutandis* for io-conditionals.

[5] By 'p sees X *veridically*' we mean that an image of X is formed on the retina of p's eyes that somehow 'causes', via the optical nerve and the brain, a corresponding mental event of p, usually called a *perceptual event*. Then delusions, imagining things and dreams do not fall under $\text{Sees}(\cdot, \cdot)$, which is what we want.

[6] We denote True and False with capital first letters in order to distinguish them from true-in-a-model and false-in-a-model, respectively (concepts which are going to play a major rôle further on in this paper). We mean Truth in the plain sense of correspondence with an actual fact, or in some deflationary sense, or whatever other philosophical account of Truth as long as it does not *overtly* prejudge on the realism-issue with respect to unobservables and modalities. Troughout this paper we assume Tarski's Convention T: $\text{True}(\boldsymbol{\psi})$ iff $\boldsymbol{\psi}$.

Since an so-conditional is a *modal* proposition, Ladyman's tension between the epistemic concept of observability and the pragmatic modal concepts now seems to have been fully restored in CE, because the New Rough Guide (2) explicitly states their logical connexion. Is CE in trouble after all?

The restored tension is, again, not real, or so Monton & Van Fraassen [2003: 410-411] claim in their response to Ladyman. CE is not in trouble. They essentially admit that not *all* subjunctive conditionals are *flatus vocis* or pragmatic. For instance, $\boldsymbol{\phi} \mathrel{\Box\!\!\rightarrow} \boldsymbol{\phi}$ is a perfectly acceptable logically True subjunctive conditional, and New Rough Guide (2) is an epistemic subjunctive conditional. Then they go on to *deny* that 'inflationary metaphysics', *e.g.* belief in the existence of an infinitude of other possible worlds treated on an equal ontological footing with the actual world, called *Modal Realism*, is needed to make sense of New Rough Guide (2) in particular and of subjunctive conditionals in general; they claim that, on closer inspection, subjunctive conditionals do not require Truth-conditions that transcend what in principle we can publicly verify or falsify, or rely on the inflationary metaphysics of Modal Realism (cf. Section 8[7]). Monton and Fraassen write [2003: 410] (our italics):

> The sense in which counterfactuals are here held *not* to have an *objective truth-value* is that they are *in general context-dependent*. The context in which they are asserted is one in which the speaker is holding something fixed, which together with the antecedent implies the consequent. What is held fixed *tends to include a good deal of unformulated general opinion*, but also *features specific to the case*. The conditional has a truth-value, relative to such a context; but that value will vary with context. When it is true it is because *a certain conditional* in this contextual background is *logically true*. (3)

This is wholly consistent with Van Fraassen's [1981: 194] construal of subjunctive conditionals more than twenty years ago. So if one takes objectivity to imply context-*independence*, as Monton & Van Fraassen tacitly do (but we reject), then counterfactuals do not have objective truth-conditions on their sketchy construal. But if one considers the *objectivity* of the proposition to be safe as long as the Truth-conditions can *in principle* be publicly verified or falsified in the actual world without recognisably 'subjective elements' entering the process, then subjunctive conditionals remain as *objective* as their indicative siblings. This seems to be case in quotation (3). Therefore the objectivity of $\Box\!\!\rightarrow$ is not lost, in contrast to what Monton & Van Fraassen claim on the basis of the dubious tacit assumption that context-independence is necessary for objectivity. So much for objectivity — nothing essential will depend on this difference in meaning ascribed to the word 'objective'.

[7] Is it necessary to be a Modal Realist in order to believe in objective modalities in nature? The working-hypothesis in this paper and in Van Fraassen's writings on modality is an answer in the affirmate. Let us conjecture, for those who answer in the negative, that Van Fraassen will classify any account of objective modality in nature as 'inflationary metaphysics' because it will transcend the phenomena in the actual world, far beyond what can in principle be tested. With this conjecture in position, we move on.

Let us now try to state more precisely what Monton & Van Fraassen are saying in quotation (3) about how to construe $\Box\!\!\rightarrow$. Theirs is essentially a Quinean construal. Let C be some context. Let $\mathbf{P}[C]$ be the 'relevant part of the Propositional content of C', thus including "a good deal of unformulated general opinion" and "features specific to the case".[8] Let $\boldsymbol{\phi}, \chi$ be two statements. What is proposed in quotation (3) seems to be the following:

$$\text{True}(\boldsymbol{\phi} \,\Box\!\!\rightarrow \chi) \ \text{ in context } C \quad \text{iff} \quad \big(\mathbf{P}[C] \wedge \boldsymbol{\phi}\big) \vdash \chi \,. \tag{4}$$

The "certain conditional" which is "logically true" in quotation (3) then must be the following one (by virtue of the Tarski-Herbrand Deduction Theorem):

$$\big(\mathbf{P}[C] \wedge \boldsymbol{\phi}\big) \longrightarrow \chi \,. \tag{5}$$

Let us apply this construal of subjunctive conditionals to New Rough Guide (2). When we use 'context' and 'circumstance' interchangeably, we obtain the

> **Construed New Rough Guide.** Concrete object X is *observable* iff there are contexts which are such that the relevant part of their propositional content and the proposition that X is in front of us together imply that we see X.

In terms of our abbreviations and of construal (4) of subjunctive conditionals, the New Rough Guide is this:

$$\text{Obs}(X, \mathcal{E}) \ \text{ iff } \ \exists\, C,\ \forall\, p \in \mathcal{E} \,\Big(\big(\mathbf{P}[C] \wedge \ \text{Front}(p, X)\big) \longrightarrow \ \text{Sees}(p, X) \Big) \,. \tag{6}$$

The conclusion is that the modal character of the so-conditional belongs to its surface grammar; what Monton & Van Fraassen are saying here is that when we analyse the New Rough Guide (2) *properly*, we see that deep down it is a non-modal statement posing as a modal one (4).

Psillos' Problem. New Rough Guide (6) is however circular, in that it is like a lamp that only works when another lamp has already been switched on so that it has become otiose. We explain.

Consider the following two so-conditionals.

(A) If Bas *were* 10 km from Callisto in his flying saucer and *were* to look through the window, then he *would see* this moon of Jupiter.

(7)

(B) If James *were* to stand in front of a living Tyrannosaurus in broad daylight with his eyes wide open, then he *would see* this enormous reptile.

Only if so-conditionals (7) are True does criterion (6), the construal of the New Rough Guide (2), license us to say that Callisto and a living Tyrannosaurus are observable. Well,

[8] The notion of the 'propositional content of a context' is something *we* bring in here, by conceptual necessity, because only propositions can 'imply' anything, which is what Monton & Van Fraassen are saying (3). That this is the way to go is also clear from Fraassen [1981: 194].

in the Section called 'The Vagaries of Observability' of his [1999: 193-200], Psillos argues (to stick to our examples) that to imagine (A) Bas looking at Callisto from his flying saucer and then seeing this moon of Jupiter means to enter a *science fiction context*. We can add that putting (B) James in front of a living Tyrannosaurus also means to enter a *science fiction context* — a journey in H.G. Wells' time machine or some genetic doctoring as in Spielberg [1993] to be specific. If science fiction contexts are permitted, Psillos continues, we can consider the following science fiction context: Bas is put in a yellow submarine, is decreased in size several orders of magnitude, and the tiny sub with content is injected in the blood stream of a human being; then blood cells, microbes and in fact the entire microscopic world becomes *observable*.[9] In another science fiction context, blood cells are increased to the size of pancakes by some reverse device, which makes them, and all other microscopic objects treated similarly, *observable-to-us*; cf. Psillos [1999: 190-191]. So by being sufficiently imaginative in telling science fiction stories, we can make every single object observable. It is all a matter of dreaming up some context. Calling an object unobservable is a lack of imagination.

This is, surely, a *reductio ad falsum* of the New Rough Guide (2).

So, clearly, if we want to avoid Psillos' conclusion that the observability-distinction cannot be drawn coherently because we can make every object observable, not every context 'dreamt up' is permitted to occur in the class of contexts where $\exists$ in (6) ranges over: a context with Bas as an interplanetary traveller going beyond where no man has gone before, and a context with James in a time machine going to the Jurassic Age, where no man has gone before either, are both *permitted*; but a context with some 'microscopised' human being (henceforth *microman*) or a context with pancake-sized blood cells must be *forbidden*. Where, then, to draw the line? What *is* the range of $\exists$ in (6)? Call this *Psillos' Problem*.[10] If this rescue attempt of the New Rough Guide (2) is to succeed, a solution of Psillos' Problem is mandatory.

The line cannot be drawn between science-fiction contexts and science-fact contexts because some science-fiction contexts definitely are permitted (7). The line also cannot be drawn between contexts which involve actual objects only and those which involve also possible objects that are fictional (not actual), because the concept of observability (which we are in the process of grounding by means of subjunctive conditionals) and the concept of existence are, according to Van Fraassen [1980: 18, 197], *logically independent* (each does not imply the other):

A flying horse is observable — that is why we are so sure there aren't any ...
(...) (8)
The ride of the headless horseman is an observable event, but not an actual one.

[9]According to our best physical theories about matter, scaling material objects is not possible; see Appendix A for a quick argument. We gloss over this.

[10]Let us mention here that various distinct arguments have been propounded to the same effect as how Psillos sees his argument (by M. Friedman, A. Kukla, A. Musgrave and others), namely establishing that the observability-distinction cannot be coherently drawn within CE; we have handled these arguments elsewhere, in a satellite paper to the present one. Cf. Muller [2004].

So these are not successful rescue attempts of the New Rough Guide (2). We try another one.

A solution of Psillos' Problem seems to be emerging when we point out that not everything can be permitted to be done to members of $\mathcal{E}$. Some things *make them loose their membership in* $\mathcal{E}$. For instance, making human beings a few orders of magnitude *smaller* is forbidden, as is surgically implanting X-ray microscopes in their eye-sockets, and as is removing their eyes altogether. But moving human beings about in space and time is permitted, as is presumably a visit to the hair-dresser, loosing a finger, or a kidney, or two legs, or perhaps even becoming colour-blind. Some physiological changes are definitely permitted and even mandatory, whereas others are definitely forbidden. (We notice parenthetically that space and time travel also result in physiological changes, for instance in the brain, where new experiences will be stored which can be remembered, told, written down or discussed at a later date.) Psillos has made that much abundantly clear. Why are many physiological changes permitted, in spite of the fact that some of them seem quite drastic? The answer is, of course, that these changes seem irrelevant for matters concerning observability. Loosing your finger or your legs does not affect your eye-sight, but shrinking you a few orders of magnitude supposedly does affect it. When we remind ourselves that our ability to observe determines the subclass of observables of the class of all concrete objects, it seems that the following *Criterion* for allowing a context is the right one: a context is *permitted* iff the physiological changes of members of $\mathcal{E}$ occurring in this context (if there are such changes at all) leave the class of observables invariant; and a context is *forbidden* iff it is not permitted. Psillos' Problem solved?

What a pity we happen to be in the process of explaining a guide for deciding what an observable is! Only if we already can decide what an observable is can we draw the required distinction between permitted and forbidden contexts by means of *Criterion*. In this fashion the New Rough Guide (2) is only useful if it has no use anymore. In other words, this rescue attempt of the New Rough Guide faces a *reductio ad circulum*.

How to break this conceptual circle? How to draw the line between forbidden and permitted contexts without surreptitiously relying on the concept of observability? This is Psillos' Problem all over again. If CE is, to borrow Ladyman's expression, to be a "tenable philosophy of science", it must give a precise, comprehensive and non-circular solution to Psillos' Problem. A viable rescue attempt of the New Rough Guide (2) is needed.

The Context Problem. Further, we also submit that Van Fraassen & Monton's description of 'a context' is too vague and too general for the philosphical task it is required to perform, which is, ultimately, grounding the epistemic distinction between observable and unobservable concrete objects, which in turn grounds the distinction between knowledge and pragmatics.[11] The problem how to make 'context' here more precise and rigorous than "a good deal of unformulated general opinion" and "features specific to

[11]Uttering '*Context!*' seems a *deus ex machina* of the past fifty years of philosophy. Are you in trouble? Contextualise! We consider such utterances without further explication and clarification more like a philosophical prayers — rather than philosophical arguments.

the case" we call the *Context Problem*.

Musgrave's Problem is the problem how CE can acquire, for every concrete object X, the belief (that it is True) that X is observable or the belief (that it is True) that X is unobservable. CE needs to answer this question in order to have objective grounds for demarcating the objective scientific knowledge that every accepted scientific theory includes from what is its pragmatic toolkit [2003]. We have called this problem 'Musgrave's Problem' because it has arisen in the context of a piercing argument due to A. Musgrave [1985: 208] to the effect that CE cannot solve this problem. Succinctly, the argument says that if we *accept* a theory and by implication its unobservable posits, we cannot come to believe that is True that the posits (whether they exist or not) *are unobservable*, because the epistemic policy of CE prescribes to remain neutral to whatever is being asserted about unobservables and *a fortiori* this includes its being unobservable. Van Fraassen [1985: 256] has responded to Musgrave, but this response is not enough to solve Musgrave's Problem. For the present purposes it suffices to know that elsewhere we left Musgrave's problem unsolved but promised to solve it (Muller [2004: § 5]). Since Musgrave's Problem has everything to do with observabililty, the present paper is the appropriate place to fulfil that promise.

Modality. In the dialectic above we have seen how observability and modality have become intertwined, but observability remained the concept in the limelight; now we draw modality into the limelight. We claim, with Ladyman [2000], that any tenable view of science must provide a general and comprehensive account of modality in science. To emphasise, this claim is not a conclusion drawn from the dialectic we have reviewed above, but if "the central motivation" for CE is "regarding how to make sense of science best", as Monton & Van Fraassen put it [2003: 421], then CE must make sense of modal language in science and CE must do so without Modal Realism. Although Monton & Van Fraassen [2003: 406, 420] have submitted that CE and Modal Realism are *logically compatible* because CE is a view of science and the other a view of modality, they have also admitted that adopting Modal Realism would scandalise one of the pivotal motivations for CE, namely to have a view of science "without inflationary metaphysics". Indeed, CE and Modal Realism are *philosophically incompatible*.

Aims of this paper. The central aim of this paper is to propound a rigorous criterion of observability that can be taken as the semantic grammar (Wittgenstein) that governs the use of 'observable' and that solves, or dissolves, Psillos' Problem, the Context Problem and Musgrave's Problem. The other aim is to provide a rigorous account of modal language in science, notably including so-conditionals, without Modal Realism and without even mentioning possible worlds. We also aim to connect observability to the possibility to observe.

Preview. We begin by hunting down a scientifically informed guide to observability, formulated in completely extensional language, even without indicative conditionals; this hunt will be partially successful (Section 2). Then we define Truth-conditions for so-conditionals (Section 3) and propose a rigorous criterion for observability in terms of so-conditionals; this criterion ought to be taken as a rigorous version of the New Rough Guide (2) (Section 4). We show how it solves the Context Problem (Section 5), Psillos' Problem (Section 6) and Musgrave's Problem (Section 7). Then we provide a succinct and precise non-realist account of the notions of possibility, contingency and necessity in the framework of scientific theories and models (Section 8). Finally, we demonstrate the existence of a strong logical connexion between observability and the possibility to observe, thereby vindicating the vulgar tongue rather than slightly revising it (Section 9).

2 Scientific Guides

In the dialectic reviewed in the previous Section, we have seen Monton & Van Fraassen responding to the exposed flaw of the conditional Rough Guide (1) by saying that it should be understood as a *different* conditional (as a *subjunctive* one rather than as an *indicative* one); this led to the problem how to define objective, actual Truth-conditions of subjunctive conditionals; the 'solution' they provided gave rise to Psillos' Problem and to the Context Problem. Another response to the exposed flaw of the original Rough Guide (1) is to formulate a fresh guide that involves *no* conditional statements at all. In the present Section we make an attempt to do precisely this. We argue that although this attempt certainly performs better as a *useful* guide than the guides we have seen so far, it cannot be crowned as the flawless criterion of observability either, because it too is flawed. Yet we shall reap the fruits from this new dialectical move further on.

To direct the mind, let us first see how we can characterise another anthropomorphic and vague property of a concrete object in non-conditional and objective terms: 'passability' of a door-frame, meaning our ability to pass the door-frame when the door is open; passability means passability-*for-us*. An objective, rigorous, non-anthropomorphic criterion that involves neither modal language nor conditional statements is the following one: a door-frame is *passable* iff it is about at least 2.10 meters high. Of course the choice of 2.10 m is *anthropomorphically motivated*, no question about it, but the criterion itself only states a particular height and does not mention human beings or their properties, in contradistinction to the Rough Guides we have seen so far. We have 'taken ourselves out of the equation', so to speak. Such taking-out we now attempt to do for observability.

Let us first get rid of an objection against finding features of an object that constitute its observability. Fire and brimstone from Monton & Van Fraassen [2003: 412] (our italics):

> The very first obstacle is that for a philosopher to identify the contingent factors in general that constitute observability in general would run precisely counter to Van Fraassen's contention that *what is observable is an empirical question*. Given this view, any such philosophical enterprise must end up as *armchair science* — worst in the empiricist's catalogue of *philosophical sins*, next to psychologism — or as *metaphysics of the same ilk as Modal Realism*.

We are puzzled. Van Fraassen [1980: 57] states that observability is a matter of empirical inquiry, not of philosophical analysis. Well, empirical inquiries have results. The empirical inquiries into observability have been pursued actively in the 1950s and 1960s and have come to an end (or a provisional end) some time ago. Enough results have apparently been gathered.[12] Why, then, not try to extract a useful criterion of observability from the results of these inquiries? This is not "armchair science", let alone "metaphysics of the same ilk as modal realism"; it drawing conclusions from empirical inquiries. It is armchair *philosophy* all right — armchairs, the eminent place where most philosophy is conducted — but also philosophy *based on the results of precisely the empirical inquiries that according to Van Fraassen are the only legitimate source of information concerning observability.* Do Monton & Van Fraassen only want to pay lip-service to science or are they prepared to getting down to it? Or is there today still something unknown that we absolutely must know before we can decide whether an object is observable? Once more, most if not all "contingent factors" have been identified some time ago and are lying there for the taking. Why let them lie waste?

Further, Monton & Van Fraassen [2003: 414] say about the question 'What is observable?' that "in practice we must rely on our best theories to answer the question". In practice we *must* rely on our best theories but not in principle? For the principled matter there is even a more reliable basis for answering the question than our best theories? What might that be? Empirical inquiry? But the results of empirical inquiries and our best theories are tightly linked, are they not? Anyway, here come some of the empirical inquiries Van Fraassen has been asking for.

So, which properties of a concrete object constitute its observability? We turn to Graham [1965], which is a collection of research and review papers about the visibility of all kinds of concrete objects and the conditions under which they are seen by test-persons.[13] The following scientifically informed guide to observability emerges from the investigations in Graham [1965]:

Graham's Guide. $\text{Obs}(X, \mathcal{E}) \text{ iff } \text{Macro}(X) \wedge \text{Light}(X)\,,$ (9)

where $\text{Macro}(X)$ abbreviates 'X is macroscopic', and $\text{Light}(X)$ 'visible light comes from (is emitted from or scattered by, and not only transmitted by) X or its neighboring surroundings'. By definition *visible light* is light having an intensity that lies above the 'sensitivity-threshold' of the natural light detectors of the members of $\mathcal{E}$, the human eye.[14] We next elucidate the two conjuncts that constitute Graham's Guide (9).

[12] All current research into the physics and biology of the human eye is research about the cognitive capabilities of the visual system as a whole and about where precisely in the brain what happens that is relevant for seeing; which objects can be seen and under what circumstances — the relevant questions for us — is now a depleted area of research because, apparently, all interesting questions have been sufficiently inquired into; cf. Graham [1965].

[13] There is a case to be made to extend the concept of observability to other sense organs besides the eyes. We won't make it here and thus equate observability with visibility.

[14] In another, more literal sense, light is *invisible*, as the well-known experiment with the laser beam and

To be able to see an object, it must be larger than a certain size. This is why electrons and DNA-molecules are unobservable to us: they are too small to be seen with the naked eye. This much is obvious. So we take 'macroscopic' to stand for 'having a minimal size'. What is this minimal size? Test persons can just resolve a grating of equidistant vertical black and white lines in front of them when the width of the lines subtends about 1 minute of arc (1°). But to see whether a thick black vertical line is cut and the top part is slightly horizontally shifted (a so-called 'vernier displacement'), the shift can be as small as 3 seconds of arc — a black spot of about 0.01 mm at a distance of about 1 m subtends such an angle; cf. Graham [1965: 325-326]. In these cases bright illumination is assumed, such as broad daylight. These and similar photometric data suggest taking the following for 'minimal size':

Criterion. Macro(X) iff
X has a size such that at about 10 cm it subtends a spatial angle of about 1°. (10)

We have chosen 10 cm in criterion (10) because this is roughly the distance below which healthy eyes have difficulty in focusing. At a distance of 10 cm we can easily see a printed point, but not at 10 km. Of course, 9.97 cm would also do, as would any distance a bit larger than 10 cm, but 0.01 cm will not do — if you press a sheet of paper against your cornea, you will not see anything.

The scientific characterisation of light according to classical electro-dynamics is as electro-magnetic radiation having a wavelength between, roughly, 400 and 800 nanometer (1 nm = 10^{-9} m) and perhaps having a minimum intensity; and according to quantum-theory as a stream of photons each one having a particular wavelength in the range just mentioned (the energy E_λ of a single photon of wavelength λ equals hc/λ, where h is Planck's constant and c is the speed of light). We can make do without any of these scientific characterisations; we take *light* to be a primitive concept and simply claim it is clear what we mean by the word 'light'.

The sensitivity-threshold of the eye, which we need to delineate Light($\cdot$) in Graham's Guide (9) more sharply, is a complicated story; it depends on whether we talk about the rods or the cones in the retina, whether there is photopic or scotopic illumination, on the wavelength of the light, on how long we are allowed to look, on the history of the eye just before we look, and on whether the object is at rest or in motion with respect to the eye. For example, when a person is situated in a dark room for a while, he can register a flash of yellow light (wavelength $\lambda \approx 510$ nm) of about 100 photons, lasting 1 ms and subtending 1°; cf. Graham [1965: 154]. Longer exposures make the eye less sensitive, up to a factor 100; for red light ($\lambda \approx 700$ nm), the sensitivity drops by a factor of 10,000 in comparison to yellow light; for $\lambda \approx 650$ nm, the sensitivity of rods and cones coincides, but for $\lambda \lesssim 500$ nm the rods are about three orders of magnitude more sensitive than the cones; cf. Graham [1965: 158, 72]. Hence, to be on the safe side, we can choose for the

the vacuum glass-bell demonstrates. *We* mean 'visible' in the sense defined in the sentence to which this footnote is appended.

sensitivity-threshold in $\text{Light}(\cdot)$ the wavelength-dependent curve $s : \lambda \mapsto s(\lambda)$ of the cones, as depicted in Figure 4.6 in Graham [1965: 72], multiplied by a factor 100 because we want to be sure to see concrete *objects* over some period of time (for at least one second, say), not merely register tiny flashes of 1 ms in the dark of night.

In the description of the predicate $\text{Light}(X)$ we explained 'light comes from X' to stand for 'light is emitted or scattered by X and not only transmitted by X'. We have included the expression 'and not only transmitted' to prevent that any macroscopic object which is perfectly transparent becomes *observable*, because if an object lets all light pass as if it were not there (save perhaps an invisibly small part of the light), we should conclude that it is *unobservable* rather than observable. (Of all kinds of stuff in the universe we are aware of, water comes closest to being transparent; glass reflects between 5%-10% of the light that falls on it, and is therefore always visible by broad daylight.)

At this juncture the question obtains whether we can propose Graham's Guide (9) as a genuine criterion that governs all our use of the word 'observable'. Well, it does not fall prey to the devastating criticisms that were levelled against the Rough Guides discussed in the Introduction. In particular, neither the Context Problem nor Psillos' Problem arises! So in that sense it is already a considerable improvement upon the Rough Guides (1) and (2). It does, however, fall prey to a different but equally devastating criticism.

Consider a macroscopic object which is not a source of visible light and which during its entire existence is always in the dark. Think of fish the size of goldfish which live near the bottom of the ocean, in the deep black see, out of reach of sunlight. They neither emit nor scatter any light during their existence and therefore make conjunct $\text{Light}(\cdot)$ False, which means that Graham's Guide (9) renders them *unobservable*. But if we somehow catch them and transport them to the surface, we shall see them. Not a single soul will doubt that — there are pictures of specimen of various species. Examples like these can be provided *ad libitum*. Therefore, as a necessary condition for observability, Graham's Guide (9) fails. $\text{Macro}(X)$ is a necessary condition for the observability of X all right, but not $\text{Light}(X)$.

We can think of no improvement of Graham's Guide (9) whilst remaining to talk in non-modal and non-conditional terms that evades the objection of the fish in the deep black sea. At one point, we pondered the following criterion: $\text{Obs}(X, \mathcal{E})$ iff $\text{Macro}(X) \wedge \neg\text{Transp}(X)$, where $\text{Trans}(X)$ abbreviates that 'X is transparent'. Observable objects are exactly the non-transparent, macroscopic objects! That seems right on the money. But 'transparancy' can only be captured in conditional terms: *if* light were to fall upon X, *then* all light would go right through X, save an at most invisible part of it. So this criterion also needs $\Box\!\!\rightarrow$, as did the New Rough Guide (2). But not all is lost.

The fish from the deep black see have not torn Graham's Guide (9) apart, they have only wounded it. For we can accept unhesingtately Graham's Guide (9) as providing a *sufficient condition for observability*; and being macroscopic surely is a necessary one. Let us call this the

Scientific Guide. $\big(\text{Macro}(X) \wedge \text{Light}(X)\big) \longrightarrow \text{Obs}(X, \mathcal{E}) \longrightarrow \text{Macro}(X)\,.$ (11)

We emphasise that the Scientific Guide (11) is free of modal and conditional talk, is not anthropomorphic and is useful in that it contains information gathered by empirical inquiries — which goes into the abbreviated expressions — that can be compared with the description of the object X under consideration. The Context Problem and Psillos' Problem dissolve in the presence of the Scientific Guide (11), which therefore is superior to the Rough Guides of the Introduction (Section 1). Already we have gone beyond Van Fraassen.

We now return to the New Rough Guide (2) and make our own attempt to rescue it, because we want a *criterion*, *i.e.* a condition which is both sufficient and necessary.

3 Subjunctive Observation Conditionals

In contradistinction to an indicative conditional, which is True whenever its antecedent is False, a subjunctive conditional with a False antecedent (a counterfactual) can very well be False:

(C) If Bas *were* 1 km from the surface of Callisto in his flying saucer and *were to look* through the window, he *would not see* this moon of Jupiter.

(D) If James *were to stand* in front of a living Tyrannosaurus in broad daylight with his eyes wide open, he *would not see* this enormous reptile. (12)

Our prime examples will be the so-conditionals in (7), which hopefully will come out as True, and the ones in (12), which hopefully come out as False.

We take a scientific theory to be a set of Suppesian models (= set-theoretical structures).[15] Call object X '*an object of model M of theory* $\mathbf{T}$' iff there is a (non-tautological) statement about X of the language of $\mathbf{T}$, denoted by $\mathcal{L}(\mathbf{T})$, that is made true by M. If we want to make a $\mathbf{T}$-model of a situation in which Bas is involved, say, we can always assign the name 'Bas' to one of the appropriate object-variables in $\mathcal{L}(\mathbf{T})$; in this fashion, we add all the names of the members of $\mathcal{E}$ to $\mathcal{L}(\mathbf{T})$. In this sense almost every particular object, whether it exists or not, is an object of (some model in) theory $\mathbf{T}$.

Since the wave theory of light, which is a sub-theory of Faraday-Maxwell electrodynamics, is the relevant accepted scientific theory which describes how light behaves at the level relevant for questions of observability, we take the wave theory for $\mathbf{T}$. Rather than to consider *all* models in this theory, we consider the subset $\mathbf{L}$ of models of the following two types:

$$\left\langle\, \mathbb{R}^4,\ S,\ \mathrm{e}_p,\ X,\ \vec{E}\,\right\rangle \quad \text{and} \quad \left\langle\, \mathbb{R}^4,\ S,\ \mathrm{e}_p,\ \vec{E}\,\right\rangle . \tag{13}$$

Here $\mathbb{R}^4$ represents (is a Cartesian co-ordinate frame on) Minkowski space-time; S is a light-source (a concrete object); e_p are the eyes of member p of our epistemic community

[15] Together with relevant data structures and embeddability-relations, which we gloss over here. Cf. Fraassen [1980: 64-69], [1989: 217-232], Muller [1998: 253-307].

($\mathcal{E}$), modelled by small concave lens (the lens of the human eye) and a little screen a few centimeters behind it (the retina) having a certain resolution-power and sensititivy-threshold (matching these of the humena eye); X is some concrete object; and $\vec{E} : \mathbb{R}^4 \rightarrow \mathbb{R}$ is the electric field of the light emitted by S, which is the electric component of the solution of Maxwell's equations.[16] The first type of model in **L** (13) describes how light emitted by S is scattered by X into e_p; the second type describes the situation in which the object itself emits light ($S = X$, so to speak), some of which falls into e_p. For future convenience we define $\mathbf{L}_@ \subset \mathbf{L}$ to be the set of exactly the *actual* models in **L**, where an *actual* model is a model that saves some phenomenon, observed or not, that occurs in the actual world. Then $\mathbf{L}_@$ goes proxy for the 'part of the universe seen through the eyes of **L**'.

Let $\mathrm{true}(M, \chi)$ abbreviate: model M renders statement χ of $\mathcal{L}(\mathbf{T})$ true. How to define this? Van Fraassen's formal account of the 'semantic view' of physical theories yields a formal definition of $\mathrm{true}(M, \chi)$; cf. Fraassen [1972: 305]. A standard Tarskian definition of satisfaction is another possibility ($M \models \chi$). But equally good may be some informal account of how Suppesian models make statements true. As soon as one has some account of truth-in-a-model, we can move on. We can also consider **L** as a truth-maker:

$$\mathrm{true}(\mathbf{L},\ \xi) \ \text{ iff } \ \forall\, M \in \mathbf{L} :\ \mathrm{true}(M,\ \xi)\ . \tag{14}$$

This ξ is a **L**-*theoretical truth*. We emphasise that Truth and truth-in-a-model, $\mathrm{True}(\chi)$ and $\mathrm{true}(M, \chi)$ respectively, are conceptually distinct. But we claim that *in the following particular case*, which is the case of the Truth of an so-conditional, the following definition, which defines Truth in terms of truth-in-a-model from an accepted scientific theory (namely **L**) that has saved all relevant phenomena so far, is exactly right (remember Convention T):

Definition (Subjunctive Observation Conditional).

$$\mathrm{Front}(p, X) \mathrel{\Box\!\!\rightarrow} \mathrm{Sees}(p, X) \ \text{ iff } \ \mathrm{true}\big(\mathbf{L},\ \mathrm{Front}(p, X) \longrightarrow \mathrm{Sees}(p, X)\big)\ , \tag{15}$$

with similar definitions for when negation-signs stand in front of antecedent or consequent, or both.

One can now straightforwardly argue that definition (15) renders the so-conditionals in (7) True and those in (12) False. Consider (A) in (12). Suppose James is in front of a Tyrannosaurus in broad daylight with his eyes wide open according to some model $N \in \mathbf{L}$. We can always construct such a model. Then light falls in the eyes of James, forms an image on his retina after being refracted by the lens of his eyes ($\mathrm{e}_{\mathrm{James}}$), of an intensity which lies above the sensitivity-threshold of the eye. The light from the sun is reflected by the Tyrannosuarus (Tyr.) because it is a non-transparent macroscopic object. So N makes it true that James sees the reptile:

$$\mathrm{true}\Big(N,\ \big(\mathrm{Front}(\mathrm{James}, \mathrm{Tyr.})\big) \ \longrightarrow\ \mathrm{Sees}(\mathrm{James}, \mathrm{Tyr.})\Big)\ .$$

[16] The contribution of the magnetic component $\vec{B} : \mathbb{R}^4 \rightarrow \mathbb{R}$ to the intensity of the electro-magnetic field is about 16 orders of magnitude smaller than the contribution of the electric component, because the intensity is proportional to $|\vec{E} + \vec{B}|^2$ and $|\vec{E}| = c|\vec{B}|$, where c is the speed of light, which is about 3×10^8 m/s; therefore we have neglected $\vec{B}$ in the structures in (13).

It seems we are in business.

4 A Rigorous Criterion

At this point, the rigorous criterion of observability seems obvious:

Criterion. $\text{Obs}(X, \mathcal{E}, \mathbf{L})$ iff $\forall\, p \in \mathcal{E}\big(\text{Front}(p, X) \;\Box\!\!\rightarrow\; \text{Sees}(p, X)\big)$. (16)

This is a scientifically informed and anthropomorphically motivated construal of the New Rough Guide (2) by using definition (15). We next proceed by making a number of systematic remarks about it, in order to elucidate it further and make the case that it is good.

(i) The very first question to ask is whether criterion (16) can serve as the semantic grammar (Wittgenstein) of the word 'observable', in that it can be taken as the sole rule that governs our common use of the word 'observable'. Does rule (16) save all the linguistic phenomena? Consider the following statements:

- A point in a piece of printed text on paper is observable.
- A living Tyrannosaurus is observable.
- Electrons are unobservable.
- The moons of Jupiter are observable. (17)
- Black holes are unobservable.
- Pegasus is observable.
- Kelvin's knot-molecules are unobservable.

A particular point, such as the one on this 'i', is a small actual object we can see; call it Y. Let p be an arbitrary member of $\mathcal{E}$. There is some some model $M \in \mathbf{L}$ describing the situation of the black, light-absorbing object Y on a light-reflecting (white) background, and some light source S emitting light of a particular intensity falling on Y, such as the sun or a lamp. In M the eyes of p (e_p) are positioned 20 cm, say, in front of the point. So M makes $\text{Front}(p, Y)$ true by construction. By applying the laws of ray-optics, which follow from $\mathbf{L}$, we can draw the image of the point on the retina of e_p, after the reflected light from the white paper has been refracted through the lens of e_p. The light falling on the retina, forming an image of what is being seen, lies far above the sensitivity-threshold of e_p, which is to say that M makes $\text{Sees}(p, Y)$ true. Admittedly this is only a qualitative sketch. But it ought to be clear that when particular numbers are put in (intensity of the light source, *etc.*), criterion (16) will be satisfied; this is beyond doubt and this is sufficient for the present purposes.

Similar stories involving models of **L** can be told for all objects occurring in (17). For a Tyrannosaurus, *vide* Spielberg [1993]. Electrons and Kelvin's knot-molecules are so tiny that light 'does not see them' in the same sense as a tidal wave 'does not see' a grain of sand. Black holes are unobservable for a reason which is suggested by the very name that J.A. Wheeler honored them with.[17] We now simply conjecture that if a criterion can save the seven linguistic phenomena in (17), it can save them all.

(ii) With the aid of (i) it is easy to find the logical connexion between criterion (16) and the Scientific Guide (11). **L** (13) makes the following statement true:

$$\begin{aligned} \big(\mathrm{Macro}(X) \wedge \mathrm{Light}(X)\big) \quad &\longrightarrow \quad \big(\mathrm{Front}(p,X) \longrightarrow \mathrm{Sees}(p,X)\big)\ , \\ \big(\mathrm{Front}(p,X) \longrightarrow \mathrm{Sees}(p,X)\big) \quad &\longrightarrow \quad \mathrm{Macro}(X)\ . \end{aligned} \tag{18}$$

(We leave spelling out the argument of (18) as an exercise. Hint for the second conditional: if some model makes $\mathrm{Sees}(p,\mathcal{E})$ true, then follow the light-rays in backwards direction from the image on the retina-modelling screen in e_p so as to end up with a minimal size of the object.) Remember that the Scientific Guide (11) emerged from empirical inquiries into the visibility of various kinds of objects under various conditions. Since **L** saves all phenomena involved, one should have expected the kind of strong connexion between $\mathrm{Obs}(X,\mathcal{E},\mathbf{L})$ and Scientific Guide (11) as expressed in (18). Good thing this expectation has been fulfilled.

(iii) Pegasus and the headless horseman are fictional objects big enough to be seen by us (8). We can easily construct a model from **L** of $p \in \mathcal{E}$ being in front of Pegasus and seeing this horse with wings (which is parenthetically far too heavy to be able to fly away). From this we see that criterion (16) vindicates that the observability of an object is independent of its existence, *i.e.* whether it is actual or fictional (8). Good thing.

(iv) The first Rough Guide (1) was flawed because it rendered observable virtually all unobservables that never are in the presence of a member of $\mathcal{E}$. This is why one should never require io-conditionals to be *sufficient* for observability. But they certainly ought to be *necessary*. For every $p \in \mathcal{E}$ and every object X:

$$\text{If}\quad \mathrm{Obs}(X,\mathcal{E},\mathbf{L}),\quad \text{then}\quad \mathrm{Front}(p,X) \ \longrightarrow_{\mathbf{L}} \mathrm{Sees}(p,X)\ , \tag{19}$$

where we define the **L**-indicative conditional ($\longrightarrow_{\mathbf{L}}$) as follows:

$$\boldsymbol{\phi} \longrightarrow_{\mathbf{L}} \boldsymbol{\psi} \quad \text{iff} \quad \forall\, M \in \mathbf{L}_{@} : \mathrm{true}(M, \boldsymbol{\phi} \longrightarrow \boldsymbol{\psi})\ , \tag{20}$$

where $\boldsymbol{\phi} \longrightarrow \boldsymbol{\psi}$ is the usual indicative conditional ($\neg\boldsymbol{\phi} \vee \boldsymbol{\psi}$). Since $\mathbf{L}_{@} \subset \mathbf{L}$, so-conditionals entail io-conditionals but not conversely, which is as it should be.

Suppose that X is an observable (Premise). By virtue of criterion (16) and definition (15) it follows that every model $M \in \mathbf{L}$ makes the relevant io-conditional true, in terms of which $\Box\!\!\rightarrow$ is defined. Then this holds for every $M_{@} \in \mathbf{L}_{@} \subset \mathbf{L}$. *Q.e.d.*

[17] Although black holes are objects whose existence can only be explained by the General Theory of Relativity, they can be modelled in **L**: as regions in space-time of a particular size absorb all incoming electromagnetic radiation. For this size we then choose the Schwarzschild radius.

Another good thing.

(v) How about the fishes living in the deep black see which wounded Graham's Guide (9)? They are harmless, for we can construct a model $M \in \mathbf{L}$ such that every such macroscopic fish is in front of an arbitrary member $p \in \mathcal{E}$ in broad daylight and p sees it veridically. Then M makes Front(p, fish) and Sees(p, fish) true, which is to say that according to criterion (16) in combination with definition (15) the fish is observable. Yet another good thing.

(vi) In Remark (i) we mentioned 'the laws of ray-optics'. This may have set off the alarm in some minds. For it seems that we rely some conception of 'law of nature'; every such conception needs to distinguish between laws of nature and accidental regularities; say that laws licence subjunctive conditionals whereas regularities do not; but subjunctive conditionals rely for their Truth-conditions on a set of possible worlds, defined as worlds where everything happens in accordance with the laws of nature. This is the familiar circle known from debates about half a century ago. Our definitions of observability (16) and of so-conditionals (15) do not rely on the concept of a *law of nature*; they rely at most on a particular conception of what a *scientific theory* is, and in fact only on what the wave-theory of light is (**L**). The circle never arises here. When we say 'the laws of ray-optics' we mean no more than what goes under that name in textbooks on optics: implications of Maxwell-equations given a certain situation and certain boundary conditions, described by sentences of $\mathcal{L}(\mathbf{L})$ and made true by some appropriate model; we could have said as well 'what the Maxwell-equations say about light rays'.

5 The Context Problem

We begin by emphasising that our criterion of observability (16) relies on a (part of a) specific physical theory (**L**) and therefore is admittedly not theory-independent, in flat contradiction to what Van Fraassen [1980: 57-59] requires:

> I regard what is observable as a *theory-independent* question. It is a function of facts about us *qua* organisms in the world.

See also the displayed quotation in the beginning of the Introduction (Section 1) and the one of Monton & Van Fraassen at the beginning of Section 2.

Once more, the fact that for the objective Truth-conditions of a *specific* subjunctive conditional we rely on what science tells us about it is, we submit, a virtue rather than a vice. On what else should we base such Truth-conditions? On common sense? On intuition? From where will Monton & Van Fraassen obtain their "good deal of unformulated general opinion" and "features specific to the case" (3)? When dealing with such specific subject-matters massively inquired into by science we should base it on the results of the scientific inquiries, and surely not on the results of polls organised to find out what "general opinion" is. Come on. In science we generally find a reliable basis for drawing inferences about the world. This is exactly what we have done: the results of these inquiries are absorbed by **L** (13) and are made manifest in the Scientific Guide (11), which is implied by $\text{Obs}(X, \mathcal{E}, \mathbf{T})$ (18). We therefore conclude that we have succeeded in improving upon the too vague and too general "good deal of unformulated general opinion" and "features specific to the case" by means of the models in **L**. The Context Problem arises no more.

Monton & Van Fraassen [2003: 409] also express their fear that if observability were theory-dependent, two different theories might produce conflicting judgments about the observability of some object. We never heard of two *accepted* scientific theories such that one theory judges an object to be observable and the other the same object to be unobservable. Their fear is irrational.

Interesting to mention that Monton & Van Fraassen [2003: 414] have admitted that "in practice we must rely on our best current theories to answer the question 'What is observable?'." So as a practical criterion, criterion (16) is good by their lights. But not as a principled criterion? Why not? What would such a principled criterion look like? The one part of "the final physics and biology"? Yet Monton & Van Fraassen (*ibid.*) also say they don't believe that "ideally rational scientific inquiry will someday end" so there never will be a final physics and biology. So 'principled criterion' is more like a 'never-never criterion'. Completely useless it seems. We propose to lift our criterion (16) to the status of a principled one. Whenever in the future certain revisions to **L** will prove necessay in the light of newly discovered facts, then we shall review whether criterion (16) needs revision too. If it does, then we shall be glad to make the necessary revisions. If the principled criterion is a fruit of scientific inquiry, then this is how it ought to be.

6 Psillos' Problem

One can see **L** (13) as legislator, separating the 'permitted contexts' from the 'forbidden' ones: the permitted ones are exactly the models of **L** (13), everything else is forbidden. A fictional object like Psillos' microman is unobservable, because we can construct models in which members of $\mathcal{E}$ do not see him when in front of him in broad daylight. Microman himself is not a member of $\mathcal{E}$. *His* eyes do not occur in the models in **L** (13); by definition only the eyes (e_p) of the members of $\mathcal{E}$ appear, all of which are actual inhabitants of planet Earth. Since $\forall$ in criterion (16) ranges over $\mathcal{E}$, whatever microman can see and cannot see has no effect on what is observable, any more than what a cat and a bat can and cannot see. Pancake-sized blood cells are, of course, observable fictional objects, on a par with Pegasus and King Kong — that was never really a problem. Psillos' Problem is solved.

At this point Van Fraassen can say: why can I not use the same strategy to separate permitted from forbidden contexts and stick to my notion (4) of a subjunctive conditional? Psillos' Problem will be solved if I require the eyes of the actual members of $\mathcal{E}$ to be present in permitted contexts; if in some context they are not present, the context is forbidden. Such a requirement is anthropomorphically motivated, but as a solution to

Psillos' Problem it is not visciously circular because observability is not mentioned in the putative set-theoretical predicate that yields **L** (13).

We would applaud this move. We would applaud it because it would mean that Van Fraassen would have set sail in our direction. But if and when Van Fraassen were to set sail in our direction, then we would ask: why not sailing all the way and join hands with us at our destination, formed by the models of **L** (13), so as to celebrate a scientifically inspired solution of the Context Problem? Stopping half-way leaves this problem unsolved. Why stop half-way if you can go all the way to safety?

7 Musgrave's Problem

Musgrave's Problem was how in principle to acquire, for every concrete object X, the belief that (it is True that) X is observable or the belief that (it is True that) X is unobservable. This is needed to guarantee the objectivity of the demarcation in accepted scientific theories between which part is knowledge of the world and which part belongs to the realm of pragmatics. Application of the extant epistemic policy of CE makes it impossible to solve Musgrave's Problem. Therefore the policy stands in need of extension. We explain.

Van Fraassen's extant epistemic policy is for propositions of accepted scientific theories. Let $\boldsymbol{\psi}(X)$ be a proposition which is only about concrete object X and belongs to the language of some accepted scientific theory. Call $\boldsymbol{\psi}(X)$ *empirical* iff X is real (= actual) and observable; in terms of abbreviations:

$$\mathrm{Emp}\big(\boldsymbol{\psi}(X)\big) \quad \equiv \quad \mathrm{Real}(X) \wedge \mathrm{Obs}(X, \mathcal{E}, \mathbf{L}) \,. \tag{21}$$

The epistemic policy of CE now prescribes to believe in the Truth of $\boldsymbol{\psi}(X)$ iff $\boldsymbol{\psi}(X)$ is empirical; and to remain neutral with regard to the Truth of $\boldsymbol{\psi}(X)$ yet accept it iff it is not empirical, in which case X is fictional (= not actual) or unobservable, or both. As we succinctly explained in the Introduction (Section 1), Musgrave pointed out that a constructive empiricist cannot belief that it is True that electrons, say, are unobservable because ' $\neg$Obs(e)' is not empirical and thus he must adopt a neutral attitude towards ' $\neg$Obs(e)'. A constructive empiricist cannot believe that electrons are unobservable!

To solve Musgrave's Prolem, we propose the following epistemic policy, which we take to be wholly in the spirit of CE. One should belief in the Truth, right? Our criterion (16) gives Truth-conditions for $\mathrm{Obs}(X, \mathcal{E}, \mathbf{L})$ which are verifiable. Nothing now prevents us now from prescribing that a constructive empiricist should believe that (it is True that) X is observable iff $\mathrm{Obs}(X, \mathcal{E}, \mathbf{L})$ is True; and believe that (it is True that) X is unobservable iff $\mathrm{Obs}(X, \mathcal{E}, \mathbf{L})$ is False. Musgrave's Problem is hereby solved.

An obvious *sufficient* condition for believing in the Truth of $\mathrm{Real}(X)$ is: for some $p \in \mathcal{E}$, $\mathrm{Sees}(p, X)$ is True ('seeing is believing'). An equally obvious *criterion* for remaining neutral with respect to $\mathrm{Real}(X)$ is: $\neg\mathrm{Obs}(X, \mathcal{E}, \mathbf{L})$. And a *necessary* condition for believing in the Truth of $\mathrm{Real}(X)$ is: X is a posit of an actual model of some accepted scientific theory. This all seems to be in perfect harmony with CE, or so we claim.

8 Modality without Inflationary Metaphysics

For the sake of future reference and to have an idea what we are talking about, we begin by listing some examples of modal talk in science:

(E) When a piece of dry paper is lit (in the air), it will *necessarily* burn.

(F) The fact that the best adapted species will survive in the long run is a biological *necessity*.

(G) A *perpetuum mobile* of the second kind, which is a machine that produces more mechanical work than it consumes energy, is a physical *impossibility*.

(H) Bricks *necessarily* fall downward when dropped (near the surface of the Earth). (22)

(I) It is *impossible* to prepare a quantum-state having an indeterminacy in position and momentum such that their product is smaller than $\hbar/2$.

(J) The mass of the electron in Dirac's relativistic wave-mechanical theory of the electron is a *contingent* matter.

From the various papers and Chapters in books of Van Fraassen [1980: 196-203], [1981], [1989: 65-68], and from Monton & Van Fraassen's [2003] reply to Ladyman [2000], there emerges the following view of CE on modality. In order for CE to ground its claim that CE makes sense of science, CE must tell us how to understand modal statements that occur in science, *e.g.* the ones in (22); this includes telling us how to reason with them and to provide them with a semantics. This is a project for the philosophy of language, not for metaphysics. An empiricist account of modality must in particular not rely on Modal Realism, because this is a shining example of anti-empiricist 'inflationary metaphysics', transcending experience to a bizarre extent. Van Fraassen [1989: 68] speaks about "a robust denial that there are other possible worlds — for possible-world talk is then only a picturesque way to describe models." For Van Fraassen [1980: 202], the locus of modality occurring in science lies in the models of accepted scientific theories. Thus the programme of CE is to replace the metaphysical entity of a possible world with the abstract entity of a Suppesian model, which is a set-theoretical structure living in the domain of discourse of set-theory, and then to mimic what modal logicians do — but now in the language of 1st-order set-theory and its deductive apparatus, which is classical 1st-order predicate logic.[18] If and when the programme succeeds in reducing every modal proposition in

[18]One may object that the abstract objects in the universe of discourse of set-theory (unobservables) also transcend experience to a bizarre extent. True, but since mathematics is indispensable for science and all mathematics used in science can be reduced to set-theory, we are already committed to *accepting* this domain

science to some non-modal proposition in the framework of scientific theories and models — or explains how this in principle can be achieved — then all modal propositions can be treated on an equal footing with their extensional brothers and sisters. We then have eliminated the modal terms and hence shown they are respectable. Specifically, we consider this programme to be successful iff we can answer questions [a]-[d] below.

[a] What are the extensional translations of the notions of possibility, necessity and contingency?

[b] What is the extensional translation of a subjunctive conditional? (23)

[c] What does it mean to say that modal statements are True or False?

[d] What is the epistemic policy for modal statements?

[**a**] Let **T** be an accepted scientific theory; let $\boldsymbol{\phi}$, $\boldsymbol{\psi}$ and χ be statements; and let $\mathcal{L}(\mathbf{T})$ be the language of **T** enriched with names of all concrete objects we want to talk about (the language need not be formalised). We define the modalities *de dicto* as follows.

Definitions. $\boldsymbol{\phi}$ is a **T**-*possibility* iff
$\boldsymbol{\phi}$ belongs to the language of **T** and some models in **T** make $\boldsymbol{\phi}$ true:

$$\Diamond_{\mathbf{T}}\,\boldsymbol{\phi} \;\equiv\; \boldsymbol{\phi} \in \mathcal{L}(\mathbf{T}) \;\wedge\; \exists\, M \in \mathbf{T} : \mathrm{true}(M,\ \boldsymbol{\phi})\ ; \tag{24}$$

$\boldsymbol{\psi}$ is a **T**-*necessity* iff
$\boldsymbol{\psi}$ belongs to the language of **T** and every model in **T** makes $\boldsymbol{\psi}$ true:

$$\Box_{\mathbf{T}}\,\boldsymbol{\psi} \;\equiv\; \boldsymbol{\psi} \in \mathcal{L}(\mathbf{T}) \;\wedge\; \forall\, M \in \mathbf{T} : \mathrm{true}(M,\ \boldsymbol{\psi})\ ;\ \text{and} \tag{25}$$

χ is a **T**-*contingency* iff
χ belongs to the language of **T** and some models in **T** make χ true and some other models make not-χ true (make χ false):

$$\triangle_{\mathbf{T}}\,\chi \;\equiv\; \chi \in \mathcal{L}(\mathbf{T}) \;\wedge\; \exists\, M \in \mathbf{T} : \mathrm{true}(M, \chi) \;\wedge\; \exists\, M' \in \mathbf{T} : \mathrm{true}(M',\ \neg\chi)\ , \tag{26}$$

We then have the following version of Aristotle's Law: for every $\boldsymbol{\psi} \in \mathcal{L}(\mathbf{T})$: $\neg\boldsymbol{\psi}$ is a **T**-necessity iff $\boldsymbol{\psi}$ is a **T**-impossibility. In symbols:

$$\Box_{\mathbf{T}}\ \neg\boldsymbol{\psi} \quad\Longleftrightarrow\quad \neg\ \Diamond_{\mathbf{T}}\,\boldsymbol{\phi}\ . \tag{27}$$

of discourse anyway. Certainly, a view of CE on mathematics and abstract objects ought to be developed, but not in the current paper; we conjecture that remaining neutral with respect to the domain of discourse of set-theory and all its inhabitants will prove the most natural epistemic attitude for CE as we know it because they are ineliminable unobservables. For such an attempt, see Bueno [2002].

The first two examples in (22) can easily be taken care of, because in these statements the modalities arguably are *flatus vocis*; they can easily be re-formulated without changing the meaning *in any scientifically significant sense*:

(E′) When a piece of dry paper is lit (in the air), it never happens that it does not burn, it always burns.

(F′) Biological mechanisms determine that the best adapted species will always survive in the long run. (28)

The translations of the other four examples non-trivially invoke the definitions we provided above:

(G′) *No* model of Thermodynamics makes it true that some device produces more mechanical work than it consumes energy.

(H′) In *all* models of Newton's universal theory of gravitation in which *only* the Earth occurs and masses of about 1-10 kg ('bricks') are let go off above its surface (not higher than 1 km, say), these masses follow a trajectory toward the center of the Earth.[19]

(I′) *Every* model of standard quantum mechanics wherein a physical system is prepared in some state makes it true that this state always is such that the product of the indeterminacies of position and momentum is larger than or equal to $\hbar/2$. (29)

(J′) In some models of Dirac's relativistic wave-mechanics we can set the value of the mass of the electron equal to a value slightly different from its actual one without leaving thereby this theory; so '$m_e = 9.109558 \times 10^{-31}$ kg' is made true by some models and made false by others.

We now predict that all modal talk *in science* can be saved in similar fashion by means of definitions (24). Those who disagree are obliged to provide counter-examples. Until and unless such counter-examples surface, CE can claim to save all the relevant linguistic phenomena.

A word on the concept of *physical necessity*, a notion different from our **T**-necessity (25). We claim that always when a physicist speaks about 'physical necessity', he tacitly has some accepted theory in mind. We know that what is true in all models of one theory, say a statement like the Schrödinger-equation in standard quantum mechanics, is false in the models of another theory, say of relativistic wave mechanics, where relativistic wave-equations such as the Dirac-equation are always true. In models of the general theory of relativity light always bends along heavy objects, but never in models of wave optics.

[19]Notice that the italicised *only* circumvents the notorious problem of *ceteris paribus*-conditions.

Moral: *one theory's necessity is another's impossibility* and therefore 'physical necessity' is an ambiguous phrase. One could, however, define *physical necessity* as necessity according to *all* relevant accepted theories. For example, falling stones when dropped then are a physical necessity because all relevant models of both accepted theories of gravity that we have, Newton's theory of universal gravitation and Einstein's general theory of relativity, make it true.

[**b**] We have already dealt with a particular kind of subjunctive conditional, namely so-conditionals (15). One obvious choice for subjunctive conditionals generally would be the following:

$$\text{True}(\boldsymbol{\phi} \mathrel{\Box\!\!\rightarrow}_{\mathbf{T}} \boldsymbol{\psi}) \ \text{ iff } \ \forall\, M \in \mathbf{T} :\ \text{true}(M,\ \boldsymbol{\phi} \longrightarrow \boldsymbol{\psi})\ . \tag{30}$$

This would, however, be a more appropriate definition for the **T**-*strict conditional*, defined as the necessity of the indicative conditional:

$$\Box_{\mathbf{T}}\,(\boldsymbol{\psi} \longrightarrow \boldsymbol{\phi})\ . \tag{31}$$

The subjunctive conditional lies somewhere between the indicative conditional (20) and the strict conditional (31). A Truth-criterion for $\Box\!\!\rightarrow$ can be defined, mimicing Lewis [1973], by restricting $\forall$ to a subset of *accessible models* of **L**, say $\mathbf{L}_{\text{acc}} \subset \mathbf{L}$. The idea behind $\mathbf{L}_{\text{acc}}$ is that it contains exactly the models who judgment we accept when it comes to judgments about the actual world. So evidently we then have that all actual models are in there, *i.e.* $\mathbf{L}_{@} \subset \mathbf{L}_{\text{acc}}$. One can first define an *accessibility-relation*, denoted by $\sim$, which for us would be a relation between members of $\mathbf{L}_{@}$ and members of **L**, so $\sim\ \subset \mathbf{L}_{@} \times \mathbf{L}$, such that we can define $\mathbf{L}_{\text{acc}}$ as the range of $\sim$: the set of all models in **L** such that each member of it is related to some actual model.[20] According to Lewis, in each specific case or group of cases, our intuition must guide our hunt of a definition of a relevant accessibility relation. This means that there is little to say about $\sim$ in general, save that each time we define some specific $\sim$, **L** gets subdivided in $\mathbf{L}_{\text{acc}}$ and its complement. It may not even be necessary to define some $\sim$. In our definition of an so-conditional (15), we quantified over *all* models in **L**, not over only the 'accessible' ones. Then the so-conditional coincides with the corresponding strict conditional. In this case, that does not seem to give rise to any problems. We have the resources to make the distinction, but it seems alien to science. We have never seen a paper of a scientist asserting that some statement $\boldsymbol{\phi}$ is indicatively but not strictly implied by $\boldsymbol{\psi}$.

We conclude that for each specific $\boldsymbol{\phi} \mathrel{\Box\!\!\rightarrow} \boldsymbol{\psi}$ one should do two things. First, choose an accepted scientific theory whose judgment on matters occurring in $\boldsymbol{\phi}$ and $\boldsymbol{\psi}$ you trust, **T** say. Secondly, contemplate whether an accessibility relation is needed; if not, then adopt definition (30); if so, then find an accessibility relation, $\sim$ say, which will result in

$$\mathbf{T}_{\text{acc}} \ \equiv\ \{M \in \mathbf{T} \mid\ \exists\, M_{@} \in \mathbf{T}_{@} :\ M_{@} \sim M\}\ , \tag{32}$$

[20] For Lewis [1973], the accessibility-relation is a three-place relation: one world is more similar to a given one than another world. When one fixes the given world, by choosing the actual world, a two-place similarity-relation can be defined. This is what we think of *ab ovo*, because we are here only interested in Truth, that is, true-of-the-actual-world — we believe scientists are too, unlike philosophers.

and then adopt the following definition (remember Convention T):

$$\boldsymbol{\phi} \;\Box\!\!\rightarrow\; \boldsymbol{\psi} \;\text{ iff }\; \forall\, M \in \mathbf{T}_{\text{acc}} :\; \text{true}(M,\, \boldsymbol{\phi} \longrightarrow \boldsymbol{\psi})\,. \tag{33}$$

Another choice of theory can lead to different judgments about $\Box\!\!\rightarrow$, but that is exactly analogous to the modalities (25), which is a good thing.

[c] Since modal statements are now reduced tot non-modal statements, they seem to fall under the purview of a correspondence conception of Truth. Van Fraassen [1980: 90, 197], [1989: 177, 181, 192, 218]: statement $\boldsymbol{\phi}$ about the world is True iff $\boldsymbol{\phi}$ corresponds to some fact in the world. This schema presupposes there are facts in the world. Of course, without having some account, or theory, of *facts*, this Truth-schema is a useless criterion, but we gloss over this *hic et nunc* because developing such an account, or theory, lies beyond the scope of the present paper. Many will know that Douven [1996] argued that the correspondence conception of Truth gives rise to a paradox within the confines of CE. In Muller [2003] we argue that a more general and ontologically weaker re-formulation of the correspondence idea dissolves Douven's paradox. This re-formulation reads: *statement $\boldsymbol{\phi}$ about the world is True iff there are such things in the world as facts and $\boldsymbol{\phi}$ corresponds to (at least) one of them*; this schema has as presupposition no one will deny: *it is logically possible there are such things in the world as facts and $\boldsymbol{\phi}$ is about these facts*.

All modal statements now have objective, actual Truth-conditions. So much for Truth.

[d] Again, since modal statements are now reduced tot non-modal statements, they fall under the purview of the epistemic policy of CE: believe as True only those acceptable modal statements (*i.e.* modal statements relying on an accepted scientific theory) that are about actual observables only and remain neutral about all other accepted modal statements.

Readers of Fraassen [1980: 118] may wonder what we have to say about this:

> ... scientific propositions are not context-dependent in any essential way, so if counterfactual conditionals are, then science neither contains nor implies counterfactuals.
>
> The truth-value of a conditional depends in part of the context. Science does not imply that the context is one way or the other. Therefore science does not imply the truth of any counterfactual — except in the limiting case of a conditional with the same truth-value in all context.

A moment's reflection will reveal that our account of subjunctive conditionals is in full harmony with these and other passages in Van Fraassen's writings as soon as we realise there is a distinction between theoretical truths (propositions in the language of a theory **T** made true by all its models — only *their* truth is implied by the theory: they are the **T**-necessities, or **T**-truths), and other propositions, each of which can be made true by some model and false by some other model of the same theory (their truth is not implied by the theory: they are the **T**-contingencies). For **T**-truths and contingent truths it holds that they are Truths iff they correspond to some fact in the world. A constructive empiricist believes in these Truths iff the Truth-making facts involve actual observables only; otherwise he remains neutral.

9 The Possibility to Observe

Observability is our ability to observe. Yet we are now also in a position to say what it means to say that it is possible to observe object X; call this a *possibility observation statement*, or *po-statement* for brevity. Wouldn't it be nice if statements of type $\mathrm{Obs}(X, \mathcal{E}, \mathbf{L})$ turned out to be co-extensive with the po-statements after all? Let us see how we can muster this.

The relevant physical theory when it comes to observability is **L** (13). We argue that the following biconditional holds:

$$\mathrm{Obs}(X, \mathcal{E}, \mathbf{L}) \longleftrightarrow \forall\, p \in \mathcal{E} : \Diamond_{\mathbf{L}} \mathrm{Sees}(p, X) . \tag{34}$$

Sufficiency. Suppose object X is observable (Premise). Then by criterion (16), for every $p \in \mathcal{E}$ there is some relevant model in **L** which makes $\mathrm{Front}(p, X)$ as well as $\mathrm{Sees}(p, X)$ true. Hence by definition (24), $\mathrm{Sees}(p, X)$ is an **L**-possibility.

Necessity. Suppose that according to **L** it holds that for every $p \in \mathcal{E}$ there is a model in **L** such that it makes $\mathrm{Sees}(p, X)$ true (Premise). Then it also makes '$\mathrm{Front}(p, X) \longrightarrow \mathrm{Sees}(p, X)$' true, because an indicative conditional is true if its consequent is true. This means that according to criterion (16), object X is observable. *Q.e.d.*

This result is the last good thing we have on offer.

A The Quantum-Physical Impossibility of Scaling Objects

By way of a desert we show that micromen and pancake-sized blood cells are quantum-physically impossible objects. Since human beings consist for about 80% of water and water consists of molecules, let us agree that if we cannot decrease or increase H_2O-molecules in size without violating some well-established part of quantum theory, then we cannot change the size of human beings either. Consider a H_2O-molecule. The Hydrogen atom in a H_2O-molecule consists of a proton and an electron. In the ground-state, the electron is most likely to be found at a distance from the proton known as the 'Bohr-radius': $a = \hbar^2/m_e e^2$, where $\hbar \equiv h/2\pi$ (like h) is also called Planck's constant, e is the electron's charge and m_e is the electron's mass; this yields $a = 0.0529$ nm. To change the volume of a Hydrogen atom would mean to change the Bohr-radius (a). But since a is determined by constants of nature and the fixed values of the mass and the charge of the electron, we cannot possibly change it, unless we reject the quantum-theoretic expression of a. This would be tantamount to contradicting accepted quantum theory. Similar arguments hold for other atoms. Hence increased or decreased counter-parts of actual concrete objects (while leaving the number of molecules invariant) are quantum-theoretical impossibilities.

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