Modal Rationalism and Constructive Realism: Models and their Modality

Abstract

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I present a case for a rapprochement between aspects of rationalism and scientific realism, by way of a general framework employing modal epistemology and elements of 2-dimensional semantics (2DS). My overall argument strategy is meta-inductive: The bulk of this paper establishes a "base case," i.e., a concretely constructive example by which I demonstrate this linkage. The base case or constructive example acts as the *exemplar* for generating, in a constructively 'bottom-up' fashion, a more generally rigorous case for rationalism-realism *qua* modal epistemology. The exemple I choose in D. Chalmers' (2002) modal rationalism and R. Giere's (1985, 1988) constructive realism. I show by way of a thorough analysis how Giere's claims concerning modal scope are characterized as instances of Chalmers' modal rationalism, both weak and strong. In essence, as I demonstrate via Chalmers' notions, *ceteris paribus* the constructive realist ultimately opts for a comparatively wider gate, characterized by modal reasoning, to lead from the rooms of conceivability *qua* thought experiments and models, to the pastures of metaphysical possibility. Chalmers likewise tries to erect such a wider gate, in his general conceivability-possibility theses. Anti-realists, on the other hand, see a narrower passage and my contention herein is that they suffer from modal myopia, which hopefully the 'corrective vision' of Chalmers' modal rationalism can restore. In the introduction and concluding sections I sketch out suggestions of constructing 'inductive steps' from my base case, to generate more extensively general claims regarding realism *qua* rationalism.

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1. Introduction

The connection between rationalism and scientific realism has been given some consideration, albeit in broadly "externalist" (i.e., historical and value-theoretic) fashions by Boyd (1985), McMullin (1993), Psillos (1996), and Smart (1963).[i] I argue here that a more rigorous treatment of the subject can be undertaken, which highlights aspects regarding certain methodological issues centering on particular epistemological and metaphysical notions characteristic of the central role that models play in theory-formation. Such notions are usually relegated as topics of interest "internal" to the philosophy of science, insofar as particularly unique features of the domain of study (science) are abstracted away from other broadly characterized cultural or contextual issues which permeate the field.[ii] In particular, the analysis I present essentially employs the tools of Chalmers' (2002) "modal rationalism," applied to the target domain of Giere's (1985, 1988) "constructive realism."[iii]

As I discuss in greater detail below, although Chalmers' project is usually associated with his particular interpretative rendition of "2D semantics" (2DS)—e.g., as presented in Chalmers & Jackson (2001) as well as in a more inchoate form in (Chalmers, 1996) and certainly alluded to in (Chalmers, 2002)—there are good reasons not to focus excessively or exclusively on this apparatus per se, lest one lose sight of the modal forest from the semantic trees. To put it another way, as I argue below, at best one could view the issue of 2DS in Chalmers (2002) as secondary, in the face of the more essential epistemological and metaphysical claims he makes therein. Not only do the latter points provide an optimal framework in which one can subject Giere's notions to closer scrutiny, but they may also go a long way to answer to some of Chalmers' many critics (e.g., Bealer (2002) and Winstanley (2007), among others) who appear to take issue more with

his stronger claims pertaining to particular hermeneutical nuances dealing with 2DS per se. Such issues, as I claim and argue below, do not seriously threaten (or for that matter may not even apply in a relevant manner) to some of the basic points I make here concerning constructive realism *qua* modal rationalism.

Subjecting scientific realism to a more systematic modal analysis has distinct philosophical advantages which I hope shall be made apparent in the ensuing discussion below. I chose Chalmers vis-à-vis Giere, due to the many conceptual linkages the latter may offer to the former, as a constructive example, or as a "base case" for a more generally meta-inductive argument strategy that I wish to present.[iv] However, a few brief remarks can be made here regarding the "inductive step" of my argument strategy: I.e., figuratively speaking, the generally recursive features stemming from the base case that indicate what I consider to be the significant structural patterns regarding some of the significant epistemological and metaphysical features of scientific realism *qua* modal rationalism.

For starters, despite the many diverse emphases placed on methodology and epistemology by various arguments advancing the case for scientific realism[v], *au fond* this position is primarily underwritten by a *metaphysical* claim and, secondarily, by a *semantic* one:

(SR-1) The degree of explanatory coherence and predictive accuracy of any given theory **T** is in direct measure to its *truth.*

The above platitude (SR-1) is one in which *prima facie* any scientific realist would assent to.[vi] Metaphysically, of course, as entailed by SR-1, the most *prominent* one played by a theory's unobservables has to do with *representing* or corresponding to propositions and states of affairs

concerning some of the world's essential features subject to scientific prediction and explanation. Unobservables are, in that regard, *pace* the difficulties associated with verisimilitude (mentioned in n. vi. below), are better thought of as being "fallible *veracities*" than "convenient *fictions*." (Teller, 2004) Hence, the primary metaphysical claim here made by the realist has to do with assessing a theory **T**'s capacity at characterizing the transcendent[vii] propositional structure of features of the world which (in principle) could fall under scientific scrutiny.[viii] The secondary aspect of semantics concerns the specification of a **T**'s *truth-conditions*. As I discuss below, intensional semantics likewise characterizes a notion of 'meaning' fundamentally in terms of *representation* (Nimtz, 2005). Hence, the very *meaning* of unobservables hinges on their *representational* capacities.

The modal *rationalism* of Chalmers (2002) on the other hand can be viewed *au fond* as an *epistemological* endeavor—suggested (of course) by the very terms. Among other reasons, this is also signaled in Chalmers' interpretation of 2DS, in which the "vertical dimension" of worlds depict *epistemic* possibilities such that the "diagonal" or *primary* intension "capture[s] *epistemic* dependence on meaning." (Nimtz, 2005, 10, emphasis added). Moreover, "[i]t is this dependence of truth and reference on our ability to determine extensions in epistemically possible worlds that Chalmers captures by means of his framework." (Nimtz, 2005, 9). Hence, just as Chalmers' very efforts essentially attempt to set up a concordance between epistemic conceivability and metaphysical possibility, so an effort for a similar rapprochement between scientific realism and modal rationalism attempts *tout court* metaphysical-epistemological concordance in the philosophy of science. To be sure, just as Chalmers' critics (e.g., Bealer (2002), Winstanley (2007), etc.) have accused him of overreach, the same could be said for the project here, should

not the appropriate qualifications and clarifications be subsequently brought to light, as I strive to achieve in the appropriate sections below.

On an even more broad and general level (i.e., the "for all *n*…" concluding claim in my meta-inductive strategy) however, one can argue (as e.g., Fara (2007) does concerning the topic of dispositions) that the issue of modality is obviously philosophically fundamental and ubiquitous. Writes Fara (2007, 1):

> The topic of dispositions is interesting in its own right. But it derives further interest from the fact that appeals to dispositions have been made in just about every area of philosophical enquiry. There are explicitly dispositional analyses, for example, of mental states, of colors, of value, of properties…dispositions have been enlisted, in one form or another, in the service of illuminating phenomena ranging from our understanding of the logical constants to the nature of beauty. Philosophers interested in just about anything should be interested in dispositions.

One could practically substitute *salva veritate* the term 'modality' for every instance of 'disposition(/s)' and the above passage would read just as persuasively. Whether one is working in semantics, epistemology, or metaphysics, in whatever philosophical domain or specialty, i.e., philosophy of science, philosophy of religion, etc., achieving some clarity concerning a rigorous analysis of realism *qua* modal rationalism shall prove itself to be directly beneficial: For *all* philosophical fields, to varying extent and degree, wrestle with questions concerning realism versus anti-realism concerning their essential *analysanda*. To characterize such wrestling in the 'court' according to the protocols of modal rationalism, can only enhance, if nothing else, the

respective struggles with more systematically refined degrees and elements of "philosophical sportsmanship."[ix]

2. Constructive Realism-A Brief Overview

As suggested (n. iii. below) "constructive" is ambiguous, as, Hacking (1982) for instance adopts the same terminology characteristic of his version of scientific realism, which diverges substantially from Giere's (1985, 1988). In particular, Hacking and Giere differ on what constitutes the essential ontology characteristic of the basic *units of description* of their respective projects: For Hacking, it is the *experiment* (and its associated protocols of construction and design), whereas for Giere, it is the *model* (with its respective design and interpretation protocols).[x]

2.1 Constructive Realism's Ancestor: Van Fraassen's Constructive Empiricism

However, despite their divergences, both Giere's and Hacking's positions can be viewed as realist rejoinders to B. Van Fraassen's (1980) 'constructive empiricism': "To be an empiricist is to withhold belief in anything that goes beyond the actual, observable phenomena…*involving a search for truth only about what is actual and observable.*" (1980, 202-203, italics added) Moreover, a *constructive* empiricist regards the primary value of scientific theories as developing "imaginative pictures which have a hope of suggesting new statements about observable regularities and correcting old ones." (Van Frassen (1980, 1998) 1081-1082)

Van Fraassen's first passage cited above indicates the constructive empiricist's metaphysical and semantic rejoinder to (SR-1): Truth-conditions are restricted to the class of all *observables* of

a theory **T**.[xi] Van Fraassen refers to this restriction of truth-conditions as a theory's *empirical adequacy*:

(CE-1) Science aims to give us theories that are empirically adequate; and acceptance of a theory involves as belief only that it is empirically adequate…[W]hat it [**T**] says about the observable things and events in the world is true—exactly if it 'saves the phenomena.' (Van Fraassen (1980, 1998) 1069).

The subtly epistemic twist for the constructive empiricist involves this *belief* versus *acceptance* distinction alluded to above. According to Van Fraassen, realism entails that:

(SR-2) Science aims to give us, in its theories, [1] *a literally true story of what the world is like*; and [2] acceptance of a scientific theory *involves the belief that it is true*. (1066, italics added).

The anti-realist hence is free to deny either the metaphysical-semantic claim [1] of (SR-2) or the epistemic claim [2]. The constructive empiricist denies the latter[xii]:

(CE-2) [T]he literal construal of scientific language concerns our face-value interpretation of its meaning…By distinguishing…*accepting* a theory and *believing* it to be true, …constructive empiricis[m] recommends a position of agnosticism towards the theoretical [i.e., the unobservables]. (1233-1234)

Hence, given that (CE-1) & (CE-2) entail that that a scientific theory **T** makes literal truth-claims one may remain metaphysically agnostic towards (regarding **T**'s unobservables)—i.e., *accepting* **T**'s literal story insofar as it retains its empirical adequacy or "saves the

phenomena" to its fullest extent—what characterizes this rendition of empiricism as specifically 'constructive'? Aside from the role played by **T**'s "imaginative pictures" mentioned above, there resides also the essential role played by *instrumentation* and *experimentation* vis-à-vis theory *construction*. In particular, the former test the empirical adequacy and guide in the continued construction and completion of the latter, while (conversely) the latter formulate questions "in a systematic and compendious fashion" and guide the design of experiments conceived and implemented with the goal of answering such questions, among other things.[xiii] In this regard, it is worth mentioning in passing that Hacking's notion of "constructive" remains faithful to Van Fraassen's, according to the letter. Nevertheless, "[t]he [constructive realist] experimentalist does not believe in electrons because,…they 'save the phenomena'. On the contrary, we believe in electrons because we use them to *create* new phenomena." (Hacking (1982, 1998) 1164-1165). In this manner, Hacking's epistemic and methodological points echo Giere's. "From the standpoint of [constructive realism] to understand a system is to know how it works." (Giere (1985), 85) I now turn to Giere's points in greater detail below.

2.2 Giere's Constructive Realism

Though Hacking, as I briefly mentioned above, employed the term "constructive" in a mode and manner seemingly faithful to Van Fraassen to the letter, it appears that R. Giere (1985, 1988) may be far more attuned its spirit of interpretation: "In science, he [Van Fraassen] claims, it is the models, not the linguistic forms, that occupy center stage…[Moreover] the proper language for philosophical study of science is mathematics, not metamathematics." (1985, 75-76) Nevertheless, Van Fraassen's notion of empirical adequacy should give one pause, since:

> [W]e see van Fraassen constructing a model of science and attempting to show that the model [itself] is empirically adequate…Only occasionally [however]…*does he argue the case at a level of scientific practice. But it is at this level that empiricism stands or falls*...[For example,] [i]t is very difficult, I think, to save the phenomena of molecular biology, *as a scientific enterprise*…[E.g.,] [m]uch time in Crick's laboratory was spent [on]…representations of nucleic acids in their scale model [i.e., on **T**'s unobservables]…not striving merely to account for spots on X-ray photographs. [i.e., saving the phenomena]. (1985, 95-96, italics added)

In other words, it appears somewhat ironic that given the Van Fraassen's valiant efforts to bring philosophy of science down from the stratosphere of logically and meta-mathematically regimented "rational reconstructions" and plant its feet more firmly in workaday empirical soil, *au fond* his project seems to overlook the very salient features in scientific *practice* that underwrite its *empirical success*, in the *first* place.[xiv]

For Giere, as mentioned above, the *model* (understood in the cognitive sense[xv]) and its protocols dually shaping theory-construction and theory-articulation takes center stage, in terms of being the essential unit of description in this explanatory "success story" usually attributed to 'mature' scientific theories deemed (at the very least) as *reliable*. A particular example of such a model Giere discusses (1985, 75-82; 1988, 64-81) is that of the one-dimensional simple harmomic oscillator (1DSHO). The 1DSHO, in its various mathematical formulations, characterizes a prototypical "exemplar" (Kuhn, 1962) insofar is it optimally instantiates *all* of Kuhn's five essential values governing theory-choice (1977, 1998): consistency, accuracy, broad explanatory coherence, simplicity, and fecundity.[xvi] Regarding the issue of fecundity, for

instance, the 1DSHO has been employed to a high degree of predictive success to diverse and manifold phenomena in classical *and* quantum mechanics.[xvii] For the sake of simplicity, one can consider the 1DSHO in terms of the theory of classical mechanics only—which would involve (in the case of translational motion) an ideal uniformly dense mass (m) connected to a massless spring with stiffness parameter k sliding on a frictionless horizontal surface[xviii] characterized by initial conditions (x_0, p_0) (position and momentum)[xix] whose time-evolution in (x, p) phase- space is governed by the differential equations (Hamilton's equations of motion):

(Eqn 2.1) $$\frac{dx}{dt} = \frac{\partial H}{\partial p} \qquad \frac{dp}{dt} = -\frac{\partial H}{\partial x}$$

The function $H(x(t), p(t)) = T(p(t)) + V(x(t))$ is the system's "Hamiltonian" representing (in this simple case) a direct sum of functions T and V (homogeneous in p and x)[xx] which in turn represent respectively the system's kinetic energy: $T(p) = \frac{p(t)^2}{2m}$ and potential energy: $V(x) = \frac{1}{2}kx(t)^2$.

Giere asks, in this particular case: "[W]hat is the relationship between theoretical models, so conceived, and real oscillating systems such as bouncing springs, pendulums, and vibrating molecules?" (1985, 78). According to Giere, the answer depends on how one *interprets* the model's *modal scope*, of which he suggests six progressive cases (1985, 83):

Case 1. Extreme empiricism: The 1DSHO model (i.e., 'model') simply agrees with *observed* positions and velocities *to the present time.*

Case 2. Extended empiricism: The model agrees with *all* observed positions and velocities *past, present, and future.*

Case 3. Actual empiricism: The model agrees with *all* actual positions and velocities *whether observed or not.*

Case 4. Modal empiricism: The model agrees with *all possible* positions and velocities *of the real system.*

Case 5. Actual realism: The model agrees with *the actual* history of *all* (or most) system variables.

Case 6. Modal realism: The model agrees with *all possible* histories of *all* (or most) system variables.

Consider (*pace* the problems associated with verisimilitude as briefly mentioned in passing in n. i. and n. vi. below) the phrase "agrees with" to paraphrase a *similarity* relation (both in terms of *respect* as well as *degree*—e.g., n. xv. below.) "The designated real system is *similar* to the proposed model in specified *respects* and to specified *degrees*." (1985, 80) Giere argues that Van Fraassen's constructive empiricism is best characterized in terms of case 3, i.e., constructive empiricism is actual empiricism. Constructive realism, on the other hand, whether broadly or narrowly interpreted, instantiates cases 6 or 5 respectively, i.e., modal or actual realism.

So according to Giere's claims, realism versus anti-realism is an issue which can reduce to questions concerning modality.[xxi] Prior to subjecting Giere's constructive realism to Chalmer's modal rationalism (which I present in the following section below) it is important to take note of several key issues distinguishing the above cases:

(CR-1): What distinguishes realism from empiricism has primarily to do with the issue *conceivability* (i.e., *epistemic possibility* according to Chalmers): The realist makes a strong modal similarity claim by quantifying over all (or most) system variables which can (for instance) be potentially generated by all conceivable mathematizations (modulo

consistency and relevance).[xxii] The empiricist, on the other hand, would remain (at best) metaphysically and semantically agnostic: An *observable* oscillatory system ultimately is mediated via its position and momentum, to an agreed-upon accuracy.[xxiii] Any extra variables generated by some mathematization thereof, should at best (to recall Van Fraasen's quip) be seen as "imaginative pictures" aimed at 'saving the phenomena' ultimately indexed by *x* and *p*.

(CR-2): "All possible histories" represent *counterfactual* cases (i.e., metaphysical or 'secondary' possibility). Metaphysical possibility characterized counterfactually is something all 2D semanticists (Chalmers, Kaplan, Stalnaker, etc.) agree upon—as it is ultimately based on Kripkean (1980) considerations rendered precise through intensional semantics (a subject to be discussed in greater detail in the following section below.) Laying such niceties aside, however, it is intuitively appealing that metaphysical possibility should be characterized counterfactually: Certainly certain *facts* about the actual world (known *a posteriori*) must presuppose any entertainment of possible worlds. Varying such counterfactuals in the above case amounts simply to solving the Hamilton equations of motion for different (i.e., other than the actual) initial conditions. Again, the antirealist views such variations by demurring from making any metaphysical commitments thereon vis-à-vis the model. The modal realist[xxiv] (or strong constructive realist) on the other hand insists that such variations agree with robust metaphysical possibilities.

(CR-3): Combining (CR-1) and (CR-2), the constructive realist can then infer a bold conceivability-possibility claim which I shall analyze further according to Chalmers (2002) in the following section below.

3. Chalmers' Modal Rationalism-A Brief Overview

Certainly since Kant (1781, 1965) lively interest has burgeoned concerning the question of the nature of any interrelation among epistemology, metaphysics, and semantics, with their associated fundamental distinctions of *a priori/ a posteriori*, necessity/contingency, and analyticity/syntheticity (Baehr (2006), Casullo (2002), 95; Nimtz (2005), 11; etc.)[xxv] Since S. Kripke (1980) interest in exploring this question continues to burgeon with especial liveliness.

3.1 Modal Rationalism's Ancestor: Kripke's Intensional Semantics

Although (as I briefly mentioned in § 1. above) I argue here that Chalmers' modal rationalism should *not* be reduced to certain (tendentious, by the lights of some of his critics) interpretative claims he advances concerning 2DS in his (2002) as well as in other sources (1996, Chalmers & Jackson (2001), etc.), it hardly follows that brief mention should not be made concerning this particular semantic research program from which, he as well as others (Kaplan (1989a, b), Stalnaker (1978, 2004)), articulate their positions. As in the previous section, in which I articulated elements of Van Fraassen's constructive empiricism, for the central reason that Giere's and others' claims (Hacking (1982, 1998), Churchland & Hooker, Eds. (1985)) were some of his respondents, so Chalmers, Kaplan, and Stalnaker's 2DS have evolved vis-à-vis Kripke's (1980) particular development of *intensional semantics.* "[I]ntensional semantics is driven that we can model the representational properties of our language by assigning intensions to terms and sentences. From this, a significant *meta-semantical condition* follows meaning and is intimately linked to modality." (Nimtz (2007), 2)

Nimtz (2007, 1-2) summarizes such meta-semantical conditions of intensional semantics below, for any sentence S in language Σ and for any world *w*—i.e., a "comprehensive counterfactual alternative to the way our actual world is," (1) in totality $\mathscr{W}$:

(A.) Meaning is *representational*: Any sentence S's *literal meaning* is based on its capacity to *represent* states of affairs, facts, etc.

(B.) Truth conditions of S = S's representational content: I.e., the way S represents can be gauged in situations in which S is true.

(C.) Truth-conditions are truth-value distributions over possible worlds: For any world $w \in \mathscr{W}$ in accords with S's claim, S's *truth-conditions* can be specified by assigning a *valuation* v: $\Sigma \times \mathscr{W} \rightarrow \{\top, \bot\}$ such that: $v(S, w) = \top$.

(D.) Extension is *compositional*: S's formal structure is determined by the reference(s) of its descriptive terms. "[T]he extension of a sentence in a possible world is determined by the extension of its constituent terms have in that world." (2)

(E.) Intension is *compositional*: This automatically follows from the very notion of intension, which is characterized as a *function* and hence is structure-preserving regarding the (essentially Boolean) set-theoretic connectives of its domain, as well regarding the (associative) compositional map $\circ$.

To spell these generally technical points out in more concrete detail, consider the last condition (E.) in terms of Kripke's particular approach (Winstanley (2007), 20). Intensions can be partitioned into the following classes:

(i.) Term Intensions: f_T: $\mathscr{W} \rightarrow E$ where E is the class of *extensions*.

(ii.) Sentence Intensions: f_Σ: $\mathscr{W} \rightarrow V$ where V is the set of *truth-values*.[xxvi]

(iii.) Predicate Intensions: f_P: $\mathscr{W} \rightarrow \Pi$ where Π is the set of *classes* or *properties*.

(iv.) Singular Intensions: f_σ: $\mathscr{W} \rightarrow \mathscr{O}$ where $\mathscr{O}$ is the set of *individual objects*.

So, to illustrate by way of simple example, consider the sentence S: 'Bill Gates is rich.' In (binary) logic, the sentence's intension f_Σ: $\mathscr{W} \rightarrow \{ \mathsf{T} , \bot\}$ of course assigns the actual world $w_a \in \mathscr{W}$ the value T, i.e., for $S \in \Sigma$: $f_S(w_a) = \mathsf{T}$. Its subject term is of course singular, with intension f_b: $\mathscr{W} \rightarrow \{b\}$, in which $\{b\}$ is the singleton containing b (the logical constant denoting the proper name: 'Bill Gates'). The sentence's predicate intension f_R: $\mathscr{W} \rightarrow \Pi_R$ in which $\Pi_R = \{x| Rx\}$, where R is the 'is rich' predicate. Now, at w_a in the substitution instance in the free formula $[b/x]Rx \equiv Rb$ yields the true statement, which is tracked by the compositional characteristic of the intensions[xxvii]: $f_S(w_a) = f_{b \vee R}(w_a) = (f_b \circ f_R)(w_a) = f_R(f_b(w_a)) = f_R(b) = Rb$.

More important, however, note that the singular intension f_b assigns *all worlds* to the singleton $\{b\}$, i.e., proper names are *rigid designators*: Their singular intensions pick out the *same* object in every world where that object happens to exist. In this particular instance, the predicate intension for '_is famous' does *not* rigidly designate, clearly, since there's nothing substantial about being 'famous' in any metaphysically robust way. (One doesn't talk of nature 'carved at the joints' according to such social values, obviously.) On the other hand, natural kind predicates like '_is H_2O' *rigidly* designate, since metaphysically speaking this predicate is the *actual reference* (Putnam, 1975) of the natural kind (likewise rigidly designated) term 'water.'

Hence identity statements like "Water is H_2O," "'Hesperus' is 'Phosphorous'," etc., are necessary by virtue of the necessity of identity: $\forall xy[\ x = y \rightarrow \ \ (x = y)]$ *and* because their subject and predicate terms (proper names, natural kinds, actual references) rigidly designate.

Epistemically, however, such identifications of water with H_2O, etc., are clearly *a posteriori*.[xxviii] Thus, "necessary truth and *a priori* knowledge do not coincide. *Pace* Kant, metaphysics is autonomous from epistemology." (Nimtz, (2005), 3) Furthermore, objects and samples themselves, so rigidly designated, determine their *own* intension, not *how* one identifies them. Hence, "Kripke concludes that the identifying knowledge a competent speaker associates with his terms *cannot* be what determines the reference and truth-conditions of his expressions. *Pace* Frege, semantics is autonomous from epistemology." (ibid)

3.2 The General 2DS Response

One can appreciate the (superficially) historical parallels between B. Van Fraassen (1980) and S. Kripke (1980). Both are innovators, culminating by seeking to *transform* their respective traditions (e.g., empiricism and intensional semantics, respectively). Both make bold and original claims, upsetting decades if perhaps not centuries' worth of largely unquestioned fundamental assumptions concerning certain basic "isms" in philosophy and in science.[xxix] And finally, both had their host of critical respondents who argue that their claims ultimately *under-reach* to the extent that they are unable to support, in a top-heavy fashion, what perhaps appear *secunda facie* as ham-fisted pronouncements: Giere, as discussed above, accuses Van Fraassen of not having delved deeply enough into the *empirical* study of theory-formation and articulation in the sciences to support his constructively "empirical" thesis. By the same token, despite

significant differences in mutual interpretation, the 2DS research program of Chalmers, Kaplan, and Stalnaker evolved as a similarly critical response to Kripke and Putnam's intensional semantics: It is *not enough* to characterize meaning in terms of variations of truth-conditions vis-à-vis certain *facts*.[xxx] One must also consider what the sentences themselves *mean*, i.e., the speaker's *intention* (and *intentionality*), in some key instances involving indexical claims.[xxxi] Certainly, for that matter, the 2DS perspective holds that Kripke's project is not *fit* enough nor even sufficiently *developed* enough, to warrant his aforementioned counterclaims to Kant (i.e., that metaphysics is autonomous from epistemology) and to Frege (that metaphysics is autonomous with respect to semantics.)[xxxii]

As in the case of Hacking and Giere borrowing much in letter and in spirit from Van Fraassen's notion of "constructive," so in a similar manner 2D semanticists borrow and incorporate much (in letter and spirit) from intensional semantics:

> [T]wo-dimensional semanticists agree that our semantics has to account for this two-fold dependence on meaning and fact, and they agree that we can capture both dependencies relying on the apparatus of worlds and intensions familiar from intensional semantics…add[ing] the distinction between counterfactual and actual worlds…mak[ing] use of the threefold distinction of kinds of intension this effects…Put generally, *the truth of an indexical sentence in some counterfactual world depends [on] what is the case in that world, and it depends on what is the case in the actual situation,* or *the actual world,* it is uttered in…What [therefore] gets discriminated *are two different roles the very same possible worlds can play* (assuming we can specify for worlds considered as actual a centre consisting of a speaker, a place, and a time). (Nimtz (2007), 4, italics added)

So, loosely speaking, on can conceive of the 'horizontal' axis characterized *a' la* Kripke's metaphysically counterfactual worlds ($\mathscr{W}_{CF}$), referred to as 'secondary intension' in 2DS. But there still remains the 'vertical' axis characterized as 'primary' intension and indexed according to worlds considered-as-actual ($\mathscr{W}_{A}$).

A few technical clarifications:

(2DS-1): A necessary condition all 2D semanticists maintain is that the worlds considered-as-actual *must* be centered. I.e., in that regard, they must have sufficient metaphysical "internal" structure to support indexicality, involving (at the very minimum) individuation according to speaker s and his/her spatiotemporal location (x_S,t_S). One could further fine-grain and add the speaker's *point of view* (Winstanley (2007), n. 19, 23) which would necessitate S's *intentionality*. Hence[xxxiii]: $\mathscr{W}_{A} \subseteq \mathscr{W}_{CF.}$ This centeredness is necessary since, as mentioned briefly above (and in n. xxxi below), indexical claims like "*I* am in NYC" not only vary in secondary intension ("I am in *NYC*") but also nontrivially vary according to what the speaker *means* by "I" which obviously, for that matter depends upon who *is* the speaker and what his/her *intentions* are.

(2DS-2): This "three-fold distinction of kinds of intension" alluded to above by Nimtz can be precisely characterized via the following: a.) *Primary Intension*: f_P: $\mathscr{W}_{A} \rightarrow \mathscr{E}$. b.) *Secondary Intension*: f_S: $\mathscr{W}_{CF} \rightarrow \mathscr{E}$. c.) *Diagonal:* f_D: $\mathscr{W}_{A} \rightarrow (\mathscr{W}_{CF} \rightarrow \mathscr{E})$. The co-domains $\mathscr{E}$ represent generalized extension classes which can incorporate (as subclasses) the respective codomains (discussed in p. 14 above) of term, singular,

> predicate, and sentence intensions, respectively. The diagonal intension f_D "portray specifically how [an] expression's primary and secondary intensions interlock." (Nimtz (2005), 4)

So much for all that the two-dimensional semanticists *agree* upon. Differences however arise regarding methodological, metaphysical, and epistemic ways of *interpreting* the 'vertical' dimension $\mathscr{W}_A$. Nimtz characterizes this interpretative difficulty in the form of two fundamental questions (ontological and epistemological, respectively) (5):

(Q1): What *are* actual worlds $\mathscr{W}_A$?

(Q2): What is the *precise reason* 2DS requires $\mathscr{W}_A$ and primary intensions?

Though I shall discuss Chalmers' modal rationalism in particular, to get a sense of their varying projects I mention briefly in passing the answers to (Q1) and (Q2) that Kaplan (1989a,b) and Stalnaker (1978, 2004) offer as well, according to Nimtz.

Kaplan's work on demonstratives distinguishes *content* from *character*. The former applies when uttering a linguistic token, i.e. an expression occurring in a *context*—e.g., consider the token utterance S: '*I* am in NYC.' The indexical token '*I*' refers, but carries no meaning—expressing the *content* of a proposition a speaker and hearer can grasp in that particular context of utterance. On the other hand, the linguistic *type* 'I' in an expression-type (apart from context) 'I am in NYC' does not *refer*, but carries *meaning*. (Grammatically, it is a first-person pronoun, etc.) Its overall meaning expresses a *conventional rule*, i.e., *character*, that it refers to a particular speaker who would utter the token in a particular context. "[T]he sentence type ['I am

in NYC'] does not express a proposition. But having grasped its meaning, any speaker will know which proposition token of this type expresses if it uttered in a context." (Nimtz, (2005), 6). Thus Kaplan's interpretation of 2DS entails that actual worlds are *contexts* (in answer to (Q1)) and (in answer to (Q2)) "we need actual worlds and primary intensions to account for the context dependence of language." (7)

Stalnaker's 'metasemantic' approach on the other hand takes into explicit account the speaker/hearer's *mean of (re-)interpretation*: When the content of utterance goes against some conventional rule (e.g., when a speaker says "Hesperus is Phosphorus" ('*h*=*p*') but transposed them by mistake[xxxiv]) "the hearer draws on his meta-semantic knowledge that the standard semantic meaning of some expression depend on features of our actual world." (8) I.e., the hearer may respond above to the speaker's transposition by correcting him: "I understand what you're saying, we're talking about Venus. *However*, 'Hesperus' [*h*] is the name of the *evening star*, but *you said*...", etc. Hence (answer to (Q1)) actual worlds are "possible alternative environments" one may have introduced certain terms in (i.e., in the above case, assigning *h* the name of the morning star.) Actual worlds and primary intensions are needed "to capture actual-world-dependence of semantic meaning and hence to describe metasemantic facts," (ibid.), i.e., the answer to (Q2).

Chalmers' approach, which of course I shall devote exclusive attention to in the following section, is distinguished from Kaplan's and Stalnaker's in namely being the most explicitly *epistemic*. Where Kaplan and Stalnaker focus on content and character vis-à-vis utterance tokens and types, meta-semantic rules of assignment vis-à-vis reinterpretations modulo dependence of the (actual) world's particular facts, respectively; Chalmers, on the other hand,

answers (Q1) and (Q2) by arguing that actual worlds are *epistemic possibilities*, which are required to "capture epistemic dependence on meaning." (10)

In closing here, I may offer another analogy with the previous discussion—Hacking's attention paid to Van Fraassen's use of the term 'constructive' follows the latter's program more to the *letter*, since Van Fraassen was specifically referring to experimental design and construction. Giere, on the other hand, injected an explicitly *epistemic* approach—by ascribing a centrally cognitive approach characteristic of 'constructive' vis-à-vis modeling. By the same token, Kaplan and Stalnaker appear to follow Kripke's intensional semantics here *to the letter*, by applying 2DS to what may be viewed as anomalous or lacking in the Kripke-Putnam approach. On the other hand, Chalmers appears to wrestle more with the *spirit* of Kripke's approach by explicitly injecting a centrally epistemic role to counter Kripke's conclusions contra Kant and Frege alluded to above:

> [Chalmers] maintains that Kant is right. There is a deep link between necessity and *a priority*, for a sentence is epistemically necessary if and only if it is *a priori*. Chalmers also holds that Frege is right. Semantics is indeed rooted in epistemology. For the identifying knowledge a competent speaker associates with her terms, as is revealed by the epistemic intensions she associates with it, *precisely is* what determines the reference and truth-conditions of her expressions. Here, metaphysics is not autonomous from epistemology. And neither is semantics. (Nimtz (2007), 10)

3.3 Modal Rationalism-The Heart of the Matter

Openly challenging Kripke (1980) by professing an interpretative methodology which would, among other things, vindicate Kant and Frege, etc., is a risky enterprise. Chalmers has his fair share of critical respondents (Bealer (2002), Winstanley (2007), Yablo (2002), just to name a few). As I mentioned however in places throughout the above essay, there are good reasons to cleave the *general* issues centering on modal rationalism that Chalmers (2002) discusses, from his more pointedly and avowedly epistemic characterization of 2DS (1996, Chalmers & Jackson (2001)). These issues are *distinct*, but obviously not *disjunct*: They overlap to the extent of necessitating, among other things, *some* exposition of Kripke's intensional semantics and 2DS, as I endeavored to show above.

Chalmers (2002) never mentions Kant or Frege in any substantial way, and basically only explicitly discusses 2DS in an off-hand expository manner (166-167, 179). The project here, in my view, shares a resonant theme with Casullo (2002), insofar as a serious attempt is made to *epistemically* characterize the *a priori qua* as a bona fide *epistemic* notion, in its own right.[xxxv] However, *pace* traditional epistemology past and present, Chalmers certainly does *not* tackle the issue in terms of attempting to *positively* characterize what is meant by 'experience' vis-à-vis the *a priori*'s notion of "non-experiential sources of justification." This, of course, is a core theoretical problem pertaining to the analysis of *a prioricity* per se (Baehr (2006), Casullo (2002), etc.). Instead, appealing to the ubiquity of modal judgments we make, vis-à-vis epistemic conceivability and metaphysical possibility considerations (mention which was briefly made in § 1., above) Chalmers draws our attention to a venerable tradition in philosophy, utilizing *a priori* methods to make modal claims which "often…draw conclusions about matters of substantive metaphysics." (2002, 145) In this respect his project resembles Casullo's, insofar

as they both offer non-reductive analyses of this (and other) *epistemic* categories treated as fundamental non-primitive *analysanda* subject to fruitful epistemological scrutiny.[xxxvi] As the title 'modal rationalism' suggests, his point remains to elucidate how a clear *methodological* connection (without a conflation) *mediated by modality* from an *ab initio* epistemological basis to a metaphysical claim among other things comprises a cornerstone in manifold domains:

(MR-1): We find this structure [(i.) Epstemic claim (what can be *conceived*) ⇒ (ii.) Modal claim (what is *possible*, what is *necessary*) ⇒ (iii.) Metaphysical claim (*nature of things* in the world)] in many different areas of philosophy; in arguments about whether the mental is reducible to the physical (or vice versa); about whether causation and laws are reducible to regularities in nature, about whether knowledge is identical to justified true belief…there is at least some plausibility in the idea that conceivability can *act as a guide* to metaphysical possibility. (Chalmers (2002), 145-146, italics added)

Chalmers' opening claim (MR-1) above can certainly be extended into issues in the philosophy of science, as well as in the epistemic practices in many domains of science per se. The former point I make of course is the core thesis in this essay: Chalmers' characterization of conceivability-possibility *qua* modality serves as an optimal framework for Giere's modal claims in his constructive realism, and thus, in a more general sense, a substantial bridge may be built connecting elements of rationalism with realism, along lines informed by elements of contemporary 2DS and modal epistemology.

My second correlative claim above, which I will not address in much detail here (in the interests of space) may seem however faulty: Did not Hume already remind us that one should

never mix armchair *a priorizing* with *bona fide*, *a posteriori* empirical science? Certainly Chalmers does not dispute *that*! "[I]t is very implausible that conceivability entails physical or natural possibility." (2002, 146) However, by the same token, Hume's dictum can also be wielded as a heavy club[xxxvii], for it is equally naïve to claim that meaningful science does *not* (at least on *occasion*) follow the schema as outlined in (MR-1) above. In particular, one need only witness all the fruitful research by those in the "cognitive turn" in philosophy of science elucidating the *essential* role played by the activity of scientists developing 'thought-experiments'.[xxxviii] (Giere (1985, 1988), Goldman, Ed. (1993), Nersessian (2002), Petitot, et. al., Eds. (1999), Sorensen (1992), etc.) Contra "broadly Kripkean" (190) claims concerning the metaphysical necessity of natural laws, Chalmers likewise offers a similar point in defense of (MR-1) for the workaday scientist:

(MR-2) [E]ven if not all conceivable worlds are metaphysically possible worlds, we *need* a rational modal concept tied to rational consistency or conceivability to best analyze the phenomena in question…even if all worlds with different laws of nature are metaphysically impossible, it will still be tremendously useful to have a wider space of logically possible worlds (or world-like entities) with different laws, to help analyze and explain the hypotheses and inferences of a scientist investigating the laws of nature. Such a scientist will be considering all sorts of rationally coherent possibilities involving different laws; she will make conditional claims and engage in counterfactual thinking about these possibilities; and she may have terms…that intuitively differ in meaning [i.e., 'color' as used in quantum chromodynamics]…To analyze these phenomena, the wider

> space of worlds is needed to play the role that [counterfactual] possible worlds usually play. (Chalmers (2002), 193)

Claims (MR-1) and (MR-2) applied to philosophy and to science, respectively, of course are instances of Chalmers' articulated response to his answers to Nimtz' (Q1) and (Q2), discussed in §3.2 above. (MR-2) in particular of course also serves to rationally ground Giere's notions of the centrality of models, as discussed in §2.2 above. It paves the way for an articulated exposition on how modality (claim (ii.) in (MR-1)) acts as the gateway between what goes on in the scientist's mind and what gets eventually translated as reliable science, appropriately metaphysically conditioned.

So far, however, an anti-realist like Van Fraassen would probably not dispute anything I have discussed thus far, in this section.[xxxix] As suggested by Giere, the issue distinguishing anti-realism (specifically empiricism) from realism has to do with how narrow or wide one makes the modal gate—in order to pass over from the workshop of thought-experimentation and modeling into the fields of metaphysical possibility (recall Giere's six cases, discussed in §2.2 above). Wide is the gate indeed, for the realist: E.g., Giere's cases 5 and 6—the model agrees with *all* (or *most*) of the system's variables (whether mathematically concealed or revealed) for the *actual* history (i.e., individuated by the initial conditions of the system in the actual world-case 5) or *all possible histories* (i.e., counterfactual worlds, i.e. the metaphysical possibilities-case 6) of the system.

Chalmers also has reasons to argue for such a wide modal gate leading one from (epistemic) conceivability to (metaphysical) possibility. In his concluding section (194-195) he

distinguishes among three grades of modal rationalism based on qualified kinds of conceivability and possibility:

(MR-3) Weak Modal Rationalism (WMR): Ideal primary positive conceivability entails primary possibility.

Strong Modal Rationalism (SMR): Negative ideal primary conceivability entails possibility.

Pure Modal Rationalism (SMR): Positive conceivability ≡ Negative conceivability ≡ Possibility.

The distinctions and qualifications 'ideal' (versus *prima* and *secunda facie*), 'positive' versus 'negative', 'primary' versus 'secondary' I have not (as of yet) elaborated on, but are important for several reasons (both practical and theoretical). On a theoretical note, some of Chalmer's critics (in particular Winstanley (2007)) as briefly mentioned in §3.2 above have accused him (*a' la* Salmon (1982) contra Kripke (1980)) of pulling metaphysical rabbits out of semantic hats:

> Why should we believe that diagonal intensions *are* best understood as epistemic intensions? Aside from a more or less plausible story, Chalmers has done little to convince us that this is the case…a 2DS satisfying the Core Thesis would be appealing, and a response to the Kripkean necessary *a posteriori*…In addition, running repairs to the 'golden triangle' of meaning [semantics], reason [epistemology], and modality [metaphysics] would be out of this world. However, Chalmers has so far given us no reason to believe that the golden triangle is anything other than 'out of this world' qua illusory or unreal, or at least, non-actual. (23-24)

Though spatial considerations prevent me from launching into a full-fledged analysis of Winstanley's objections, I believe that several qualifications are in order. For starters, Winstanley invokes Chalmers' (2004) 'Core Thesis': "For any sentence S, S is *a priori* if and only if S has a necessary diagonal intension."[xl] (Winstanley (2007), 22). In the main, as I have pointed out in previous sections, Winstanley and others direct their focus against Chalmers' *particular interpretation* of 2DS—the above Core Thesis is one obvious instance thereof. Winstanley for instance attacks it by finding counterexamples in both directions: He drums up Stalnaker to show there can be sentences which are *a priori* and diagonally contingent, and conversely uses Davies to show that there can be sentences which are diagonally necessary but not *a priori*. (24-26) Whatever one is to make of these counterinstances[xli], by and large they would only undermine the *strongest* rendition of modal rationalism, namely MR-3's *pure modal rationalism.* So to dismiss Chalmers' larger philosophical points because of this strikes me as premature at best, if not an outright red herring.

On a practical level, the nuanced distinctions Chalmers offers applied to conceivability and possibility (e.g., 'primary/secondary,' 'negative/positive,' 'ideal/*prima* (& *secunda*) *facie*') are especially appealing to philosophers of science like Giere and others who are sensitive to fine-grained epistemic and modal notions. I daresay a scientist or a mathematician would find these nuances of interest as well: Consider a mathematician offering a 'sketch of a proof' (or similarly a physicist doing a 'back of the envelope calculation') for the existence of a solution—and finding nothing preliminarily wrong in his reasoning. This would be an instance of a notion which is *prima facie* positively conceivable. Consider more subtle cases—for a dyed-in-the-

wool constructive (e.g. Intuitionist) mathematician rejecting all indirect proofs, she is rejecting the sufficiency of using reasoning based on *negative* conceivability alone, etc.

Chalmers presents a rather nuanced and intricate analysis and exposition of the above eight different cases for conceivability and two for possibility.[xlii] Spatial considerations prevent me from highlighting every subtlety, moreover my aim is to concentrate on the distinctions relevant for the modal rationalism – constructive realism *rapprochement*, as summarized in the tables below. The upper rows and leftmost column (italicized) are the appropriate terms to substitute on (as a conjunct) on the left hand side of the biconditional:

"S is [*left column entry*] & [*top row entry*] & [*second row entry*] conceivable *iff* _____."

The individual entries under column and row header are the terms to substitute on the biconditional's right hand side:

Conceivability	*positively*		*negatively*	
	primarily	*secondarily*	*primarily*	*secondarily*
prima facie	an agent can *envision* S as *actual*	an agent can *envision* S as *counterfactual*	an agent *cannot rule out* ~S *as actual*	An agent *cannot rule out* ~S *as counterfactual*
ideally	an agent can *coherently envision* S as *actual*	an agent can *coherently envision* S as *counterfactual*	It is *not a priori* that *actually* ~S	It is *not a priori* that *counterfactually* ~S

Table 3.3.1-Conceivability Types

"Envision" and "coherently envision" are technical notions—akin to how many in the 'cognitive tradition' (Giere (1985, 1988), Goldman (1993), Nersessian (2002), Petitot et. al.

(1999), Sorensen (1992), etc.) speak, in the case of mental imaging and forming analog representations. Visualization is *not* a necessary condition. Chalmers characterizes envisioning in terms of exercising "modal imagination": "Modal imagination is used here as a label for a certain sort of familiar mental act. Like other such categories, it resists straightforward definition. But its phenomenology is familiar." (Chalmers (2002), 151). Moreover, in terms of how one "envisions" corresponds to forming *positive* conceptions:

> Positive conceivability rather than negative conceivability, seems to be what philosophers have in mind when discussing conceivability…the sort of clear and distinct modal intuition invoked by Descartes…reflects the practice in the method of conceivability as used in *contemporary philosophical thought experiments*. (155, italics added)

Coherently envisioning is perhaps the most tendentious epistemological notion, related to ideal conceivability. It is inevitably vague, but Chalmers chooses it to avoid the undesirable extremes of defining ideal conceivability too broadly, i.e., in terms of being conceivable "upon ideally rational reflection" with respect to *some* cognitive agent—even if that agent happens only to be God—or too narrowly, i.e., conceivable under ideal rational reflection only according to *human* cognition:

> I will not try to give a substantive characterization of what good reasoning consists in, or what counts as a cognitive limitation to be idealized away from. I suspect any such attempt would turn out to be open-ended and incomplete…the notion of conceivability [in any case, whether ideal or *prima facie*] is not obviously worse off than the concept of knowledge. (148)

Regarding the (two) cases of possibility—i.e. primary versus secondary, Chalmers defines them in terms of primary and secondary intension (recall §3.2 above). Recall: Given a world *w* and a statement S, if *w* is considered actual, then the *truth-value of* S (in *w*) is S's primary intension. (163). Similarly, if *w* is considered counterfactually, then the *truth-value* of S (in *w*) is S's secondary intension. (This is just a paraphrase of the more technical functional characterization of intension, as discussed in §§3.1, 3.2 above.) Hence, S is *primarily possible* if S's *primary intension* is true in some possible world *w.* S is *secondarily possible* if S's *secondary intension* is true in some possible world *w.* (164)

The nuanced epistemic distinctions that Chalmers offers, that I summarized (perhaps a bit glibly) above is enough to keep the metaphysician, logician, semanticist, epistemologist, philosopher of mind, philosopher of science *and* (as I suggest) in certain cases, the mathematician, the mathematical and/or theoretical physicist[xliii] busy for quite some time. (As I mentioned in passing in n. xlii below, nowhere does Chalmers speak of *negative* possibilia, but this is by no means a trivial issue. Certainly the issue is worthy to investigate as a research problem for the modal rationalist.) Though a cognitive philosopher of science of the likes of Giere might be interested, vis-à-vis the investigation of model-based reasoning, to explore all eight different epistemic modes as presented in Table 3.3.1 above, in terms of Chalmers' modal rationalism, he restricts the scope of his investigations to include only *ideal primary* negative and positive conceivability vis-à-vis possibility. This is obviously understandable, due to the suitably idealized nature of the topics he is investigating here and elsewhere.

3.4 Anomalies in Modal Rationalism—And Chalmers' Treatment of Them

Regarding the three different kinds of modal rationalism he presents in his conclusion (MR-3), i.e., weak, strong, and pure, Chalmers discusses problem cases or anomalies which distinguish the three renditions. This can also be of interest to the cognitive philosopher of science, especially of the Kantian bent, as such questions Chalmers poses attempt to scope out the possible limits of cognition-in-action.[xliv] The three questions Chalmers poses, and attempts to answer, are:

(MR-4) Q1. Are there *strong necessities*?

Q2. Are there *generalized inscrutabilities*?

Q3. Are there *open inconceivabilities*?

Before summarizing what these anomalies connote, it is helpful to mention here what Chalmers' assessments are: He claims to present a "strong case against strong necessities", offer "tentative reasons" to doubt in the existence of inscrutables, and admits that "the status of open inconceivabilities is unclear." (195) Nevertheless, "each of these three is a distinctive and substantial philosophical project, and…the investigation of each raises deep philosophical questions." (ibid) To pitch a case for pure modal rationalism, however, *all* three questions must be answered in the negative. But it is precisely pure modal rationalism that suggests repairing the "golden triangle" among semantics, epistemology, and metaphysics, that Winstanley (as I mentioned above) attacks Chalmers on. But as evidenced in Chalmers' (2002) essay here, and his careful qualifications of the associated problems, clearly modal rationalism does *not* entail pure modal rationalism. So again, Winstanley's objections appear all the more as red herrings.

As far as the other renditions of modal rationalism (weak and strong) go, clearly they are of greater relevance for the modal considerations suggested in Giere's constructive realism. To paraphrase weak and strong modal rationalism (WMR and SMR), they basically state that in the weak case positive (ideal, primary) entails primary possibility, whereas in the strong case, negative (ideal, primary) possibility entails possibility *simpliciter* (whether primary or secondary). Obviously in the latter case conceivability tracks possibility more closely than in the former. For instance, even if a scientist *has no clue* about how to formulate a hypothesis to explain some recalcitrant phenomena, if there is no *a priori* way to rule out the non-existence of such phenomena modulo *any* hypothesis, *actually* conceived, then by the lights of SMR, it is perfectly possible that a future theory may offer a cogent explanation thereof. To name one instance, one could apply SMR regarding some of the schemes involving speculations concerning anomalous quantum phenomena surrounding non-locality that *begin* from the paradoxes of non-locality, rather than seek to "resolve" them (see Aharonov & Rohrlich (2005)). *Provided,* however, that none of these considerations *prima facie* result in outright incoherence. "Being a physicist is no barrier to incoherence." (Schaffer (2003), 25)

Certainly, however, the workaday scientist would be more interested in scoping out *positively conceivable* hypotheses, even if this may restrict the domain in terms of gauging what may be possible. In this regard, though perhaps philosophically tepid, WMR would still prove itself to be of interest for the scientist as well as the constructive realist like Giere—if for no other reason than that WMR provides some philosophical underpinnings for Giere's case 5, i.e. actual realism, discussed in §2.2 above: The actual realist considers the model to agree with the *actual history* of *all* (or most) of the system's variables. This is an instance of WMR, since a

model is an obvious product (achievement, really) of primary positive conceivability, and to claim (as Giere does) that all or most of its variables (whether hitherto mathematized yet or not) agrees with those of the system in terms of its actual history is an example of claiming that such ideal conceptions entail *primary* possibility—i.e. a possible world conceived as actual.

However, for all of this to work, *some* of the anomalies as presented in (MR-4) above must be ruled out. Chalmers argues that that "a strong case" against strong necessities has been made (189-192) whose details I shall omit here, for spatial consideration, focusing instead only on his salient conclusion and some of his premises. According to Chalmers:

(MR-5) Statement S is a *strong necessity* if S is falsified in some positively conceivable situation conceived as actual, which nevertheless S is true in all possible worlds.

"For such necessities to exist, the space of positively conceivable situations must outstrip the space of possible worlds." (Chalmers (2002), 189). That would of course be catastrophic. To recall the discussion in §3.2 above, *every* 2D semanticist agrees that primary intension must entail *centered* worlds. Hence: $\mathscr{W}_A \subseteq \mathscr{W}_{CF,}$ where $\mathscr{W}_A$ are the worlds-conceived-as-actual, and $\mathscr{W}_{CF}$ are counterfactual worlds, i.e. metaphysical possibilities. To establish that strong necessities exist would serve as a counterexample to this necessary condition, and hence wreck the whole edifice of 2DS. This, among other things, is why strong necessities must be ruled out, to establish WMR.

To establish SMR, (Q2) above likewise must be answered in the negative, i.e., generalized inscrutabilites must be ruled out. "Tentative reasons" have been offered (174-184) whose details once again I omit. "[I]f scrutability is true, generalized scrutability is probably

true [and therefore there probably cannot be any generalized inscrutabilities]…[and] its truth would seem to reflect something deep about concepts, truth, and reason." (184) Chalmers formulates his scrutability thesis in terms of *qualitative completeness*:

(MR-6) Knowing how the world is (qualitatively) entails that we know what our terms refer to and [therefore] whether or not our statements are true. (174)

Though Chalmers builds up to the idea of generalized scrutability with quite a bit of technical rigor, the basic notion of generalized scrutability is reasonably perspicuous: It maintains that a sufficiently completely qualitative account (i.e., a *qualitative complete description* or QCD) of the relevant features of a situation is a sufficient condition to determine the reference of the terms being used. "Intuitively, a [QCD]…is a basic description from which many truths can be derived…the scrutability thesis…come[s] down to the claim that the fundamental natural truth about the world, in conjunction with indexical truths, implies all (a priori) truths." (176)

From this basic intuition, Chalmers 'precisifies' it through the notions of epistemic completeness:

(MR-7) Statement[/s] *D* is [/are] *epistemically complete* iff: (i.) *D* is epistemically possible [i.e., primarily possible: there exists some world *w* conceived as actual* such that *D* is true in *w**] and (ii) for any *F* , if $D \wedge F$ is epistemically possible, then $D \rightarrow F$. (176)

From (MR-7) and QCD, then, the scrutability thesis is put forth:

(MR-8) Scrutability thesis :If *D* is a QCD truth, then for all S, $S \supset (D \rightarrow S)$.[xlv] (178)

Loosely speaking, what the scrutability thesis MR-8 maintains is that if *D* is a QCD truth, then *D* is epistemically complete, i.e. satisfies MR-7. Generalized scrutability extends MR-8 to apply not only to a QCD of our actual world, but to *any* QCD, i.e., to *any* world *w* conceived as actual. "[I]t would be odd if scrutability turned out to be true in this world, but not in others; the thesis seems to have a much more general source than that." (183)

If the general scrutability thesis is incorrect, then general inscrutables could exist. Hence, the negative conceivability linkage with possibility (whether primary or secondary) would be broken, or SMR would not hold. Relating this to Giere's case 6 (modal realism) i.e., the model agrees with *all possible* histories of *all* (or most) system variables, is an instance of how SMR can underwrite this claim. A model which is qualitatively incomplete is an approximation an (ideally) qualitatively complete model M*[xlvi], which is ideally negatively conceivable and hence, entails possibility (both primary and secondary). Giere's case 6 captures the secondary instance, as signaled by the metaphysical counterfactual notion "all possible histories"—i.e., worlds counterfactually conceived in which the system had initial conditions differing from its actual ones.

Chalmers is less sure of himself that there are no general inscrutables. Aside from some of the problems he discusses, i.e., vague predicates, moral claims, etc., one could add into the mixture some of the debates concerning the completeness of quantum mechanics: Regarding the Bohr-Einstein debate (which essentially still goes on, in various and sundry guises) Bohr would argue that quantum theory *is* epistemically complete, but not *qualitatively* complete: One could argue that Bohr complementarity is a denial of qualitative completeness—*in principle*, no

theories can offer up a QCD—quantum theory cannot even give a complete qualitative description in phase space (position and momentum). But *pace* Einstein, this is no fault of the theory, just a metaphysical fact about our world. Hence, by denying the antecedent of MR-8, but affirming its consequent, Bohr could *formally* agree with MR-8, i.e., scrutability. But *metaphysically*, he would not, since the metaphysically interesting instance would be if both the antecedent *and* the consequent are true (i.e., there *are* QCDs, there *is* such a thing as epistemic completeness). Hence Bohr would probably include some of the aspects of quantum phenomena as instances of inscrutables.

Einstein, of course, argued for the exact opposite: His belief in local realism would certainly induce him to assent to QCD. For Einstein, it was therefore a major defect of quantum theory that in principle it could not yield up qualitatively complete descriptions. Since a good theory must *in principle* be able to do this, by the lights of MR-8, then quantum theory must be epistemically incomplete. Now another alternative for Einstein would have been to deny MR-8, and in so doing, reject the inference. He certainly did *not* do that, as he insisted all throughout the debates that quantum mechanics is incomplete, full stop. Hence one could argue that for Einstein, there should be no talk of inscrutables, at least not when doing physics! Any physical theory that suggested otherwise was simply a bad theory.

Last of all, the issue in which Chalmers is the least sure of himself is the denial of Q3—that there cannot be any open inconceivabilities. Though perhaps the most philosophically interesting—all the fuss is about restoring the 'golden triangle,' vindicating Kant and Frege, by way of aspiring to establish some knock-down argument for PMR, etc.; at least in terms of the issue of realism in the philosophy of science, let alone concerning the issues of interest of

scientists per se, undoubtedly this is of *least* concern. In fact, many may root for arguing *against* Chalmers here, as the very idea of PMR may *prima facie* offend scientists' and some philosophers' Humean intuitions. (Although I already mentioned above how Humean empiricism—i.e., Giere's extreme empiricism, case 1.--run amok and wielded as a heavy club can render science literally impossible to do, as certainly countless others including Kant (1781, 1965) have voiced similar objections). Nevertheless, as my points illustrate above, the philosopher of science (as well as the scientist) would undoubtedly be perfectly content to settle for less—i.e., WMR or SMR, as they both, as I argue above, underwrite Giere's constructive realism.

Nevertheless for the sake of closure it is useful to examine the arguments, albeit in a far more cursory fashion. If Q3 is answered in the affirmative, i.e., that open inconceivabilities exist, then the "Twilight Zone" (TZ) (statements which are negatively conceivable but not positively conceivable) would be non-empty. (183) One might think that the emptiness of the TZ has already been established via SMR in its denial of general inscrutables. But that is only half the story, i.e., the metaphysical half. Inconceivabilities represent the other aspect, i.e., the epistemic anomaly for PMR. In other words, the TZ is partitioned into two classes: general inscrutabilities as well as open inconceivabilities. (188) "[I]n order to close a potential gap between (ideal primary) negative and positive conceivability, it is necessary and sufficient to rule out generalized inscrutabilities and open inconceivabilities." (188) Chalmers offers the following definition:

(MR-9) S is an *open inconceivability* if for any QCD (of the actual world) D_W: (i.)$D_W \rightarrow \sim S$, and (ii.) S is negatively conceivable. (187)

Instances of statements potentially behaving this way are of the variety that usually keep logicians and metaphysicians awake at night, but probably no one else. Such statements would include: S_1: "There are no QCDs of our world," S_2: "There are inconceivable features of the world," S_3: "There are intrinsic nonphenomenal properties," (see Weatherston (2006)), etc.

Assuming SMR, which rules out generalized inscrutables, if one (however possible) could rule out by way of a general argument that no open inconceivabilities exist, then one can conclude that the TZ is empty. To put it another way, the 'NegPos' claim, i.e., "ideal negative conceivability entails ideal primary positive conceivability," (188) is logically equivalent to the claim that the TZ is empty. (Chalmers gives the proof of this proposition (188-189) whose details I omit here.) Hence, armed with this claim, Chalmers also shows by way of simple argument that WMR & NegPos is logically equivalent to PMR. (195) Here the argument is succinct enough to summarize: ($\Rightarrow$) Trivial: (NegPos nixes out the TZ so there is no reason to establish separately the non-existence of generalized inscrutables, etc.) ($\Leftarrow$) Possibility entails negative conceivability, "no primary possibility is ruled out *a priori*." (195) This also entails positive conceivability, by way of PMR, which in turn entails WMR & general scrutability & no open inconceivabilities, which entails WMR & (empty TZ), which entails WMR & NegPos.

IV. Conclusion

I have endeavored to show by way of constructive example how, in principle, a case can be made for rationalism vis-à-vis scientific realism. However, rather than argue my case in some 'top-down' fashion, I chose, by way of 'meta-induction' to proceed from the bottom up, in the case of a concrete exemplar (in Kuhn's sense). This 'base case' took up the bulk of this paper,

which entailed characterizing Giere's constructive realism in terms of Chalmers' modal rationalism. My hope is that if no gross errors on my part have been committed in establishing this linkage, then future papers can rigorously flesh out the 'inductive step' in the hopes of making my case more general. Conservatively speaking, all I have shown here is how one particular kind of rationalism (modal) can enjoy a rigorously logical connection with one particular rendition of realism (constructive). But again, I should hope that this is no mere example (which would not constitute an argument anyway) but an exemplar. *Au fond*, though it may prove next to impossible to establish some of Chalmers' stronger claims (let alone argue for the case that, as Nimtz suggests, he may vindicate Kant and Frege), certainly Chalmer's weaker claims in the case he makes for modal rationalism prove fruitful enough, in shedding light on issues pertaining to scientific realism.

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[i] In a broadly historical-methodological manner, Richard Boyd suggests a scientific realism based on programmatic measures. "If scientific realism is true, then the methodological practices of science provide a reliable guide to

approximate truth about theoretical matters…only scientific realism could provide a satisfactory explanation for this fact." (1985, 4) As the title of his article suggests:

> If a theological precedent must be found, the obvious choice is the dictum attributed to Pope St. Celestine I (422-432; …[though] the attribution may be faulty…): "*Lex orandi est lex credenti*," "the rule for praying is the rule for believing," or (in a freer translation) "believe what is necessary to 'rationally reconstruct' liturgical practice." For "liturgical practice" put "scientific practice" and you get a strategy for the defense of scientific realism. (32)

McMullin responds to Kuhn (1962, 1973) by suggesting that in Kuhn's five values for theory-choice (1973): accuracy, consistency, broad explanatory scope, simplicity, and fecundity, "[t]he radical challenge [for Kuhn] is not rationality, but realism." (1998, 132) From a standpoint of scientific realism, McMullin argues that one can rank scientific revolutions in terms of depth and degree—thus disambiguating notion to a broad extent. (Can one *really* consider the 'paradigm revolution' regarding the discoveries of electrostatic phenomena associated with the Leyden jar on par with the breakdown of geocentrism? According to McMullin, Kuhn's (1962) broadly descriptive attempt to answer this question remain unconvincing.) But most importantly for McMullin, a realist can *epistemically* ground some of the of the above values in such a manner that the ant-realist cannot: Broad explanatory scope, for instance, becomes an epistemic norm for the realist—the extent exhibited by a theory regarding this particular value is in direct measure to the theory's verisimilitude—which, at best, is underwritten by aesthetic considerations, for the anti-realist. Hence, all things considered, the realist can appeal to more overtly *rational* principles concerning the particular negotiation of certain values, than can the anti-realist, *even* if (*pace* Salmon's (1990) Bayesian overtures to Kuhn) no general rule-based framework can ground such values.

The "pessimistic meta-induction" (PMI) argument of course objects to any methodological programmatic arguments for realism, based on rational principles (broadly construed)—how would a realist historically account for all the *failures* of theories, which is the *rule*, rather than the exception?—is the question put forth by the PMI. To answer this, Psillos (1996) accuses the PMI of a fallacy of dichotomy-- a rational strategy based on realist presuppositions can for instance involve a *divida et impera* ("divide and conquer") middle-ground claim which: "(i.) [I]dentifies the

theoretical constituents of past genuine successful theories that *essentially* contributed to their successes; (ii) shows that these constituents, far from being characteristically false**,** *have been retained* in subsequent theories of the same domain." (S310)

Stronger methodological and value-theoretically inspired claims, suggesting that the relation between realism is one akin to entailment, include J. J. C. Smart's (1963) argument that "the canons of rational inference require scientific realism." (Van Fraassen (1980, 1998), 1075). Smart's argument is premised upon Sellars' (1962) inference to the best explanation; i.e., as a rule of inference, one should always select the theory that provides the best explanation.

[ii] To be sure, any attempts to precisely specify "demarcation criteria" which would presume to distinguish "externalist" and "internalist" studies (terms originally coined by Kuhn (1977) vis-à-vis the history of science) may prove themselves to be non-starters, given the methodologically *open-ended* nature (Scylla) of the enterprise as well as semantic (Charibdes) problem of *vagueness*. Nevertheless, regarding the study of values in science within the broader context of social epistemology, Helen Longino (1990) for instance draws a distinction between "cognitive" versus "contextual." The former pertain specifically to values and norms particular to scientific practice broadly construed (e.g. Kuhn's five values of theory-choice, see note (i) above). The latter apply to a broader socio-cultural domain (involving both moral and non-moral values). In her project, Longino envisions a notion of "objectivity" based on "transformative criticism," which would entail (among other desiderata) a more dynamically reciprocal relationship between the cognitive vis-à-vis the contextual. Such a broader discussion of Longino lies outside the scope of this essay. However, I mention her distinctions in passing, to illustrate that although no precise methodological boundary may be drawn between "internal" versus "external" studies, it does not follow that they cannot be individuated, albeit (in the case of social epistemology) in an irreducibly coarse-grained fashion.

[iii] To disambiguate this notion, as I explain as well in greater detail below, Ronald Giere's "constructive realism" should *not* be confused with Ian Hacking's (1982) version.

[iv] Adopting elements of discrete and recursively constructive principles based on logico-algebraic procedures as a general method of philosophical argumentation is a notion discussed in Desmet (2008), whose domain of analysis in

particular is A. N. Whitehead's (1929, 1979) process philosophy. Certainly the approach I take here does not incorporate the formal level of rigor as suggested in Desmet's notions of "generalized mathematics"—hence my embedding the terminology of mathematical induction above in scare quotes. This does not, however, suggest that such a more formally rigorous approach could not be implemented in a lengthier study. In this brief essay, however, I mean to exposit the central and salient philosophical points, perhaps at the expense of sacrificing in abstract rigor.

[v] Obviously, the authors I alluded to above (R. Boyd and S. Psillos) represent only a very minute sample of the voluminous literature in scientific realism, giving just primary emphasis on historical and methodological aspects thereof. Aside from Giere (1985, 1988) others advancing scientific realism from chiefly epistemological contexts, like Giere, ally themselves with the "cognitive turn" in philosophy of science (e.g., Goldman, 1993). Still others avowing a form of scientific realism based primarily on formal logical principles (syntactic or semantic) include F. Rohrlich (1988, 1994), whose work itself draws primary emphasis from the "structuralist" tradition in the philosophy of the mathematical sciences (J. Sneed (1971), E. Scheibe (1997, 1999), etc.)

[vi] *Secunda facie*, of course, (SR-1) as well as other more precise articulations of scientific realism introduce a Gordian knot of philosophical difficulties that some would claim are insurmountable to the extent that one *must* defer to *some* version of anti-realism as (if nothing else) the only viable means intellectual recovery. Aside from the PMI alluded to in n. i above, other difficulties of course center on *verisimilitude*, *theory-underdetermination*, *inductive fallacies*, etc. I mention these points in passing, though such issues lie beyond the scope of this essay.

[vii] I.e., *facts*, which are devoid of spatio-termporal indexicality. A similar issue of course underlies some of the metaphysical questions surrounding the nature of causal relata: Are the constituents of the causal relation based on transcendent *facts* or immanent *events*? (Schaffer, 2007) To the degree and extent that such transcendent features of the world can get individuated by scientific theories depends large on one's presupposed *theory of scientific explanation.* Such features would by and large be individuated in a maximally fine-grained fashion, should for example ascribe to P. Railton's (1978, 1981) 'ideal explanatory text' causal account. On the other hand, the issue of fineness or coarseness depends on the 'explanatory store' for P. Kitcher (1981) which itself is a function of its *unifying* capacity—loosely thought of as a dual-optimization procedure involving e.g. Kuhn's values of simplicity,

explanatory coherence, and fecundity. (Kitcher, of course, characterizes unification in far more explicitly rigorously precise set-theoretic terms).

[viii] Lest one voice concern over a certain "impredicative" characteristic or even *petitio principii* in some of my points, insofar as I include the term "scientific" in the predicate of some of the sentences in which I discuss scientific realism, suffice it to consider herein "features of the world that are in principle scientifically scrutable" as metaphysically primitive. Such features would necessarily involve dispositions that are not *entirely* constituted by intentionality—i.e., the latter being that peculiar mind-world relationship characterized by propositional attitudes and mental representation. (For a detailed synopsis and overview on dispositions, see M. Fara, 2006.) Of course, this is *not* to say that such (in principle) scientifically scrutable features of the world cannot be characterized by *some* degree of intentionality—e.g., the study of color-perception. For a more general discussion, see Petitot, et. al. (1999).

[ix] Certainly, when reviewing some of the debates between realists and anti-realists in the philosophy of science, such systematicity in many cases appears as sorely lacking, appearing in some cases as an all-out "intellectual brawl." Though the puns and barbs can certainly prove entertaining (witness Arthur Fine's (1984) accusations of 'foot-stomping realism' and the very *titles* composed by some of Fine's respondents like Alan Musgrave (1989)), nevertheless, to recall the Tudor musician and musicologist Thomas Ravenscroft, their overall intellectual effect seems to "burthen the wits…and maketh not the mist thinner." A little bit of general logical precision and methodological rigor suggested by modal rationalism can go a long way toward reconstructive clarity, in that regard.

[x] Following Kuhn's (1962) essential unit of description, i.e., the *paradigm*, a claim can be that Hacking and Giere's descriptive units characterize different aspects of Kuhn's. Though the connotation of "paradigm" has been accused of being hopelessly ambiguous by many of Kuhn's critics, nevertheless, *mature* sciences exhibit a paradigmatic feature with a complex internal dynamical structure with sub-constituents (analogous to a biological cell's organelles) which are readily identifiable in a (more or less) regular fashion. Such "organelles" or aspects include the "module" of theory-formation, which (in a dynamically reciprocal fashion) impacts the applications module, which likewise impacts the instrumentation/experimentation component. The latter, in turn, impacts the nomology

(lawhood from empirical generalizations of generated data) component, which, lastly, informs the theory-formation module. (1962, 10) This dynamical "virtuous circularity" indicates (for Kuhn) why mature sciences are essentially *conservative*: Aside from this relatively insular 'homeostasis' implied by this picture, serious anomalies precipitating radical paradigm-change are akin to "retooling" an industry's basic manufacturing machinery. (1962, 76) Vis-à-vis Kuhn's paradigms, then, Hacking's main focus is on the instrumentation and experimentation module, whereas Giere's "models" would dwell at the interface between nomolgy and theory--insofar as in this context, laws can be viewed "tools for model-building" (Frisch, 2005, 11). Giere's models, from a standpoint of "theory-articulation," would also reside at the interface between theory and application, for reasons that shall be made clear in the main discussion above.

[xi] A theory **T** must have at least one model **M** in which "all actual phenomena fit inside." (Van Fraassen (1980, 1998), 1069). Contrary to Giere's notion of "model" informed by the cognitive sciences, Van Fraassen is refering to the semantic-logical sense—i.e., (semi-formally) a structure **M** in a formal system **Σ** instantiating or satisfying all its axioms $A_{\Sigma} \subset \Sigma$. (E.g., the infinite flat plane is a model for Euclidean geometry, while a curved surface is not.) The tension between the two notions (cognitive versus semantic) is explored by Frisch (2005): A theory like classical electromagnetism (EM) is certainly rife with an *open-ended* set of models in the *cognitive* sense (e.g., modeling a steady-state current in terms of a continuous distribution of charges executing laminar flow) and in the semantic sense, its class of models is *empty* when applied to discrete distributions of charges (since EM's basic "axioms" or principles—i.e., energy conservation, the Lorentz force law, and Maxwell's Equations, form an inconsistent set in the discrete charge distribution case).

[xii] Elsewhere, Van Fraassen writes: "Acceptance of theories…is a phenomenon of scientific activity…if a scientist accepts a theory, [s/]he involves [her/]himself in a certain sort of research programme…" (1980, 1998; 1069) Borrowing an analogy from the philosophy of religion, Van Fraassen claims that the constructive empiricist is akin to the agnostic who nevertheless *accepts* theism as making *literal* truth-claims. Other anti-realists (e.g., positivists, phenomenalists, etc., who argue that a theory's unobservables are just convenient fictions which paraphrase ways of elegantly classifying and categorizing sets of observation-claims) denying [1] are similar in this respect to liberal

theologians who would argue for a *metaphorical* interpretation of any of the theist's claims one may deem *prima facie* as metaphysically problematic.

[xiii] Such "other things" could involve the serendipitous isolation of "novel anomalies" (Kuhn, 1962). Hacking (1982) describes in greater detail the relatively autonomous role experimentation plays, in terms of objectively isolating hitherto unknown phenomena through causal interaction within the broader patterns characterized by the particular causal nexus the instrumentation is embedded in. "No field in philosophy of science is more neglected than experiment….histories of science have become histories of theory…we lack even a terminology to describe the many varied roles of experiment." (Hacking, 1982, 1998; 1153) It needs emphasizing, however, that the metaphysics of causation is by no means trivial or perspicuous, to say the least. (See Schaffer (2007)). Depending on what particular approach Hacking adopts (which he never discusses explicitly in the above) directly impacts the kind of position concerning realism *qua* experimentation he seeks to carve. For instance, should he adopt a view that causal relata are transcendent *facts*, not immanent *events*, and individuated in a fine-grained manner like Fregean propositions—i.e., Dretske's view (Schaffer, 2007, 11-12)—then his claims for the robust methodological autonomy of experimentation get greatly watered down. On the other hand, his claims for the "objectivity" of phenomena *qua* regularities in a causal nexus would be certainly become rather plausible, in an immanentalist interpretation of relata (leaving aside here the issue concerning to what degree and extent of coarseness or fineness they should be individuated).

[xiv] This irony is further compounded when one considers that Van Fraassen was one of the prominent developers of the semantic view of theories—i.e., the position in philosophy of science maintaining that theories are essentially characterized in terms of classes of models, not (*pace* the syntactic view of logical empiricists like Carnap) sets of sentences characterized in some suitably logically regimented formal system. Moreover, as suggested by the passages above, contrary to some rather formal and meta-mathematical renditions of the semantic view classified as "structuralism" (Sneed, 1971; Scheibe, 1997, 1999; etc.) Van Fraassen's approach stays close to the actual object-language of science itself. Nevertheless, what may perhaps prove indicative of Giere's concern, Van Fraassen *does* on occasion allude to more traditionally logical metalinguistic approach in, e.g., his definition of "empirical

adequacy" *qua* model theory (n. xi above). In this regard, the naturalistic reflexivity of the "cognitive turn" (Goldman (1993)) spearheaded by Giere exhibits a methodological uniformity: The *object language* and methods of cognitive science are, in turn, bootstrapped to the metalevel to account for issues (reflected e.g. in Kuhn's values for theory-choice, n. i. above) of interest to philosophers of science: A theory's explanatory coherence, predictive accuracy, etc.

[xv] Loosely characterized as *analogue* representations essentially comprising coherent sets of mental images best depicted in terms of some dynamically evolving (weighted) graph or network: The "nodes"of this network represent the exemplary idealizations themselves, the "links" depict the *respects* of similarity in which the model(s) characterizes the phenomena of interest, which can also be "weighted" in term of *degrees* of similarity (between the idealization and the phenomena mediated by the experimental instrumentation). (Giere, 1988, 82-91). See also Goldman (1993) and Nersessian (2002). This notion of model is starkly contrasted with the logical-semantic sense—see n. xi. above.

[xvi] See n. i. above.

[xvii] E.g., celestial mechanics, semi-classical methods in quantum chemistry, quantum field theory, etc.

[xviii] Depicting of course the case of a "closed" dynamical system evolving in phase space, whose Hamiltonian becomes a "constant of the motion," i.e., $H = E$ = const. In other words, energy conservation applies. Adding physically path-dependent non-conservative dissipation terms like friction to potential term V introduce "open" systems in which, topologically speaking, their solution-trajectories can "fill" sub-regions in 2D phase space, in the sense that the such trajectories do *not* trace out closed families of elliptical curves, but rather (exponentially) decaying spirals.

[xix] The same mathematical procedures can be generalized under suitably ideal conditions of systems consisting of N constituents in 3 dimensional physical space, in which case the fundamental variables of position and momentum are generalized as $3N$-dimensional column arrays (vectors) in a $6N$ dimensional phase space.

[xx] Though linearly independent, there is still a connection between x and p: $p(t) = m\,{}^{dx}/_{dt}$ --at least for simple systems in which m remains constant. For more general cases (in which mass can vary over time, e.g., rocketships, etc.) then: $p(t) = {}^{d}/_{dt}\,(m(t)x(t)) = ({}^{dm}/_{dt})x(t) + m(t){}^{dx}/_{dt}$

[xxi] To be sure, modality is not the *only* issue distinguishing constructive empiricism from constructive realism, for Giere. Though lying outside the scope of my general discussion here in this essay, it deserves mentioning (in passing) that Giere puts Van Fraassen's pragmatic methodological musings to the test. Van Fraassen deflates Sellars' (1962) inference to the best explanation contention that Smart (1963) defends as a "following a general rule of inference" in support of a rationality claim for realism. But what, asks Van Fraassen rhetorically, does it *mean* to follow a general rule of inference? It certainly *cannot* entail having to know all the valid argument-forms in first-order logic (whether predicate or propositional). (Many Ph.D.s in a particular scientific discipline wholly ignorant of the latter get along just fine in articulating their theories, let alone developing novel ones.) Hence this notion is too narrowly conceived. On the other hand, applying *any* rule of inference will not work either, as it would be too *broadly* conceived. For instance, by the Rule of Addition one is free to infer "A or B or C or …." *ad infinitum* from "A" alone. (From "*F = ma*" the scientist can validly infer: "*F = ma*, or all squares are circles, or pigs fly in the midnight sun, or…") Van Fraassen thus responds: The scientist follows a rule of inference based on what s/he is "*willing* or *unwilling* to do…Here is a rival hypothesis [to Smart and Sellars]: we are *always willing to believe* that the theory [which] best explains the evidence, is empirically adequate." (1980, 1998; 1076, italics added). *A' la* Pascal's Wager, Giere counters Van Fraassen's latter claim by showing that a *realist* strategy (as opposed to empiricism-whether constructive or otherwise), along the line of non-Bayesian decision theory (NBDT), is "the safer bet," and therefore the more "rational" approach, all things considered. (Giere, 1985, 92-96). NBDT is employed by Giere, as it is certainly the most *pragmatic*—i.e., is devoid of Bayesian algorithms rife with their associated controversial application and interpretation in open-ended cases involving risk and ignorance. For an indication of some of the controversies surrounding Bayesian confirmation , see Salmon (1990, 1998) and Glymour (1981, 1998).

[xxii] To name one instance: Paul Dirac, using Hilbert space methods, "quantized" the 1DSHO which formally speaking entails an embedding procedure: $x(t) \mapsto |x,t\rangle_S \vee x(t) \mapsto |x\rangle_H$ where the latter denote state-vectors in the (continuous) position basis in Hilbert space, and the disjunction represents different "pictures," i.e., Schroedinger versus Heisenberg. (Note that these cases aren't exhaustive). The former, of course, represent variables (parameterized with respect to *t*) in 2D classical phase. Moreover, the functions *H* , *T, V* become, through this embedding, operators (denoted by the tilde superscript) in Hilbert space: $H = T + V \mapsto \hat{H} = \frac{(\hat{p})^2}{2m} + \hat{V}(\hat{x})$ where: $\hat{p} = -i\hbar\hat{\partial}_x$ in which the differential likewise becomes an operator. The algebra of observables in the quantum-mechanical cases is expands from the classical (Poisson) to the non-commutative Heisenberg algebra: $[\hat{x}, \hat{p}] = i\hbar\hat{I}$ (where $\hat{I}$ is the identity operator). So the quantum-mechanical rendition of the 1DSHO, the realist would claim, likewise "agrees" (i.e., is similar in respects and degrees) to essential observables for oscillatory quantum phenomena. "Actual" (i.e., constructive) empiricists (Van Fraassen) of course suspend all "agreement" talk herein by pointing out that such mathematical niceties at best give an empirically adequate characterization of microphysical phenomena. For Van Fraassen, of course, the very essential interpretative difficulties surrounding quantum mechanics, e.g., the associated anomalies of non-locality, acausality, etc., lend support to his overall pragmatically-based metaphysical agnosticism here, or so he argues.

[xxiii] Ultimately delimited of course by the Heisenberg Uncertainty Principle (HUP): $\langle\Delta\hat{p}\rangle\langle\Delta\hat{x}\rangle \geq \frac{1}{2}\hbar$ —though in quantum optics and electrodynamics there are ways to "cheat" or circumvent this seemingly absolute lower limit in products of dispersion for the canonical observables—by creating "squeezed" states of the (quantized) EM field which represent generalized coherent (minimal uncertainty) coherent states. In these special cases, an extra degree of freedom is added (the "squeeze parameter") by which arbitrarily increasing the dispersion along its axis, the HUP "disk" can be shrunk to arbitrarily small radius.

[xxiv] Giere's notion should *not* be conflated with D. Lewis' (1986), as shall be explained in greater detail in the following section.

[xxv] As with most *prima facie* 'simple' and basic notions in the fundamental enterprises (analytic philosophy, logic, mathematics, etc.) characterizing them in all their associated subtleties in a perspicuous manner free from controversy can be an intellectually formidable task—assuming it is even possible to do so, in some instances. The enterprise perhaps is akin to the quest for a proof meeting similar standards of perspicuity and rigor in the field of mathematics for such *prima facie* simple statements like Goldbach's conjecture or Fermat's Last Theorem. So likewise in the case of the above distinctions—especially with regards to the specification of *a priori*. (Baehr (2006), Casullo (2002)). Nevertheless, as a starting point, one can adopt the platitude that *a prioricity* connotes *how* certain propositions are *known* (Baehr (2006), 1): Aside from the necessary experiential basis of learning the language Λ constituting the expression of a proposition *p* in the form of a sentence(s) or *wff*(s) $\sigma_p \in \Lambda$, *if no further experience is required* to cogitate or understand what σ_p expresses, one may claim that *p* is known *a priori*. (If more experience is required, then *p* is known *a posteriori*.) Aside from these fundamental epistemic modes (essentially involving the activity of *justification*), the distinction can also be applied to expressed propositions per se: Statements expressing propositions in pure mathematics ('7+5 =12') or pure logic ('If all A are B, and all B are C, then all A are C') are *a priori* while statements expressing factual claims about the actual world ('Water is H_2O') are *a posteriori.* More complex instances incorporating the distinction include attributing it to arguments: In an *a priori* argument, all its premises express *a priori* propositions. (Baehr, 2006, 2). Much of the controversy surrounding how to best intrinsically characterize this *prima facie* epistemic notion on *epistemic* grounds (Casullo, 2002) centers on attempts to positively characterize what is meant by 'experience' (Baehr).

Platitudes for the metaphysical distinction of necessity versus contingency hinge on the notion of truth in all versus some possible worlds, respectively. *Ab initio*, one can consider the notion of a *world* as representing a maximally metaphysical possibility. (Winstanley (2007), 22) By the same token, the semantic analytic/synthetic distinction is characterized in terms of the meaning-contents of the constituent subject and predicate terms in any sentence S expressing a proposition *p*. Analytic sentences have predicate terms expressing the same meaning-contents as their associated subject terms, while synthetic statements do not exhibit this feature (the meaning contents can overlap, but they are not mutually contained in one another). Regarding semantic notion of truth-conditions "the truth of a

synthetic proposition depends not on mere linguistic convention, but [also] on how the world is in some respect." (Baehr, 2006, 3)

Obviously, in all three notions mentioned above, resonant connotations suggest themselves (e.g., the truth conditions of synthetic statements reflecting *a posteriori* notions, etc.) Indeed, some have argued that the relations among such distinctions entail logical reduction (the logical empiricist's claims of aprioricity and analyticity, etc.) Such points (relevant to Chalmers' modal rationalism) shall be discussed in greater detail above.

[xxvi] Depending on kind of logic, V can vary in cardinality from 2, i.e., $V = \{ \mathsf{T}, \perp \}$ in the typical binary logical case to $\aleph_1$, i.e., $V = [0, 1] = \{v | \ 0 \leq v \leq 1\}$ in the fuzzy logic case.

[xxvii] Regarding the technical notation: The subscript $f_{\mathrm{b}\veebar\mathrm{R}}$ represents a *disjunct union*, not a Boolean disjunction. (I.e., in this case, its associated Boolean connective would be $\veebar$ or exclusive-*or*). Moreover note that the *algebraic* convention (of reading from right to left) is implemented in the function-composition notation : $(g \circ f)(x) = f(g(x))$.

[xxviii] Kripke also (1980) by way of his 'meter-stick' example, in a dual fashion argues that *a priori* contingent statements can exist as well. Introducing term 'meter' via its 'baptism' of rigidly designating its singular intension by virtue of the standard length of a rod *S* kept in a vault in Paris for Kripke renders this identification *a priori*: "[I]f he used stick *S* to fix the reference of the term 'one meter', then as a result of this kind of 'definition'…he knows automatically, without further investigation, that *S* is one meter long." (56) Nevertheless, metaphysically this is a contingent statement, since rigidly designating 'meter' by virtue of this standard length could have well yielded other measures, based on momentary compressions, heating, cooling, etc. However, because this existence claim of Kripke's has produced more controversy (Nimtz, Wintsanley) only the former *a posteriori* necessary example is discussed above.

[xxix] In that regard recall again how unique and subtle Van Fraassen's constructive empiricism really is: He assents in an acceptance of a literalist interpretation of theoretical unobservables, where most other anti-realists (whether empiricists, positivists, phenomenalists, etc., *a' la* "liberal theologians," recall n. xii. above) would ascribe to a

'metaphorical' interpretation thereof. Recall also some of the unique methodological claims Van Fraassen makes concerning the pragmatics of rule-following, explanation, etc., in the service of the value of 'empirical adequacy.'

[xxx] Recall Kripke's contention that rigidly designated natural kind terms *determine* their own intension. Water *is* H_2O, no matter what we might conceive or imagine it to be.

[xxxi] To name one innocuous instance based on Nimtz's introductory examples. To say: 'I am in New York' depends upon certain facts upon the world, i.e. the intension of 'I am in *New York*.' But it also depends upon *intention* and *intentionality* (the speaker's mind-to-world relationship mediated by propositional attitudes and representations): '*I* am in New York' clearly varies in meaning depending on who utters it. To pick another example (Chalmers). To say '*I* am not David Chalmers' might either represent an innocuous *a posteriori truism*, *or* a flat-out *a priori contradiction*, again depending on who utters it—*ceteris paribus* concerning the totality of metaphysical facts about the world.

[xxxii] Salmon (1982) in particular complains that Kripke's semantic essentialist points vis-à-vis his metaphysical conclusions are akin to "pulling a metaphysical rabbit out of a semantic hat." (Winstanley (2007), 18). Winstanley likewise accuses Chalmers of a similar sleight-of-hand, to which I respond above that Chalmers' *modal rationalism* remains largely immune to such accusations.

[xxxiii] Equality holding in the particular case when one (for whatever reason) wishes to restrict the metaphysically possible worlds to centered ones with the same 'graininess' of individuation as the worlds conceived-as-actual.

[xxxiv] Referred to the evening star as 'Phosphorus', etc.

[xxxv] *Prima facie* this may appear as strenuously obvious, almost reflexive. However (recall n. xxv above) controversy abounds. Aside from logical empiricists arguing that the *a priori* and *a posteriori* distinction *reduces* to the semantic distinction of analyticity and syntheticity, more generally analysis of the *a priori* subdivides into the reductive (of which the aforementioned is an instance) versus non-reductive. (Casullo (2002), 98-99). The latter category gets further subdivided into non-reductive *epistemic*, which in particular focuses on *justification*, versus the non-reductive non-epistemic (which may focus *non* –reductively of an analysis of the *a priori qua* necessity, etc.)

The former gets cashed out into sub-sub-categories focusing on *source*, the *strength*, and the *defeasibility* of the justification. Casullo is critical toward all non-epistemic analyses, whether reductive or otherwise, and offers his own positive characterization of non-empirical sources of justification. The details of his argument lie beyond the scope of this essay.

[xxxvi] Chalmers makes this non-reductively epistemic point explicitly clear in several places throughout his essay. In particular, in answering an objection that ideal conceivability could either rule out (*a' la* Kripke) any talk of a substantial connection between (epistemic) conceivability and (metaphysical) possibility, *or* trivialize the connection by reducing one to the other, Chalmers steers between this Scylla and Charibdes in his response that he is not out to reduce one to the other. Moreover, "the notion of possibility enters into the definition of conceivability in such a roundabout way the thesis [of a connection but not a conflation] clearly remains substantive." (173)

[xxxvii] Certainly, in that regard, the "extreme empiricist" (Giere's Case 1, p. 10 above) wields such a club. Another issue paralleling the methodological disjunction of applying *a priori* versus *a posteriori* methods as a result of Hume's legacy in the philosophy of science has to do with what to make of deductive versus inductive reasoning. *Pace* Hume's points concerning the inductive fallacy, it certainly does *not* follow that the project of developing an 'inductive logic' is doomed from the start. It may just be much more difficult to achieve: Witness, in particular, the wrangling between those sympathetic to Bayesianism (Salmon (1990, 1998)) versus those that are not (Glymour (1981, 1998)). Of course, Bayesians do *not* corner the market on attempts to devise inductive logics (ILs) (one can be anti-Bayesian and still ascribe to the general project of developing ILs), only that this research tradition appears to be the most prominent in that regard.

[xxxviii] Of course, all those working in this empirically-motivated research into the phenomenology as well as into the cognitive process which may constitute such complex activity may not necessarily ascribe to anything that can be simply abstracted in terms of Chalmers' suggested schema in (MR-1). However, if nothing else (albeit somewhat weakly stated) it is plausible to argue that whatever is (literally) going in the minds of scientists in this regard does not at least *involve elements* of (i.), (ii.), (iii.) in MR-1 (i.e., the epistemic, modal, and metaphysical notions of 'claims') though perhaps not in any particular order, let alone that suggested by Chalmers.

[xxxix] Yablo (2002) however suggests that Chalmers' modal rationalism may fall prey to the same problem bedeviling the logical empiricist—undeterdetermination of theory by evidence (Chalmers (2002), 184). Though Chalmers does not openly avow any version of scientific realism, he resists this association with this version of anti-realism on methodological, epistemic, and metaphysical grounds:

> Underdetermination of theory by *local* evidence is no problem for a sufficiently holistic logical empiricist, but underdetermination of theory by *total* evidence is a problem…These [Yablo's] considerations are all tied to the limitations of observation, however…They do nothing at all to suggest that the complete qualitative truth (including microphysical truths) underdetermines theory. (ibid.)

In any case, Van Fraassen (as discussed in §2.1 above) is no logical empiricist—he is a self-professed constructive empiricist. In this regard, it is difficult to think that the specter of undeterdetermination would haunt Van Fraassen vis-à-vis Chalmers's modal rationalism. Van Fraassen, as discussed, is likewise comfortable with totalizing claims (recall his notion of empirical adequacy is defined via a model **M** of *all* phenomena, i.e. n. xi.above) as is Chalmers, with his notions of 'complete qualitative truth.'

[xl] Recall the notions of diagonal intension, as discussed in §3.2 above. The identity-statement S_V: '$h = p$' ("Hesperus is Phosphorus") has a necessary 'horizontal' or secondary intension modulo holding fixed the actual world w_a. In other words, modulo this world considered-as-actual, S_V is true in the actual case (w_a) but S_V is true in the counterfactual (Hesperus refers to Mars) *w*' case—recalling Kripke's essentialism. On the other hand, switching to *w*' *considered as actual* (i.e., that Hesperus *really is* Mars) then S_V is false in the 'counterfactual' case (that Hesperus is Phosphorous) as well as in the 'actual' case (since, again, 'Hesperus' *rigidly designates* Venus—but in *w' considered as actual* Hesperus is *not* Venus, period). As the table shows below, its diagonal intension is contingent. On the other hand, repeating the same exercise for S_M: '7+5=12' (ignoring, *pace* Stalnaker, issues concerning about what base one has to working in—easily done if one interprets S_M in terms of abstract cardinals; i.e. 7-ness added to 5-ness equals 12-ness) indicates a necessary diagonal intension.

w'	**F**	**F**

w_a	**T**	**T**
	w_a	w'

Table 3.3.2-2D analysis for S_V

[xli] One particular example Winstanley discusses from Stalnaker can be met with a simple response (which I allude to in n. xl above). Stalnaker's concern for statements deemed *a priori* from mathematics like "7+5=12" can (according to Stalnaker's meta-semantic conception of reinterpretation along the 'vertical' axis) exhibit diagonal contingencies, since the statement is obviously false in a world-considered-as-actual like w_{12} (i.e., a base-12 world). But this concern can be easily brushed aside, should one distinguish between *numbers* (i.e., *cardinals*) and *numerals* (i.e., their *representations*). Having said that, however, Stalnaker's second example from mathematics is more substantial: Certainly statements one would *prima facie* deem as *a priori* from geometry (the sum of the internal angles of a triangle = π radians) are false in non-Euclidean reinterpretations. In the other direction, Winstanley draws on Davies' notion of 'deeply rigid' designators (based on Davies' notion that the meanings of proper names are "completely exhausted" by their extensions) which (*pace* other 2DS approaches) would yield a necessary diagonal intension for identity statements like '*h* = *p*'. (Winstanley, (2007), 25) Well and good. However, one may *still* object to Winstanley here concerning whether or not the cases he discusses really constitute *bona fide* counterexamples to Chalmers, simply because of their *theory* (read: *interpretation*) dependence. Get rid of Stalnaker's and Davies' *interpretation* of 2DS and these counterexamples go as well.

[xlii] *Prima facie* versus *ideal*, *primary* versus *secondary*, *positive* versus *negative* = $2^3 = 8$ cases of conceivability. With no loss of generality, however, positive versus negative can be ruled out, in possibility-talk, for in the negative case this just reduces to talk of ~S being possible, whether conceived as actual or as counterfactual. But this is equivalent to talking about 'positive' possibility in the case of ~S. Granted, however, metaphysical talk of negation, when examining particular topics like causation, can result in a huge morass. (Schaffer (2003)). To name one instance: Are non-events or negative facts *bona fide* causal relata? (One speaks of instances like: "Ben ducked, which caused the boulder *not* to hit him.") Since Chalmers never engages in a general discussion concerning the logic and metaphysics of negation, neither will I, in this essay. Moreover, prima facie versus ideal likewise do not

apply in the case of possibility based on the interpretation of worlds as potentially complete (and therefore consistent and coherent) hypothetical scenarios (whether conceived-as-actual or counterfactually). Hence should one discover upon closer examination some latent contradiction buried deeply in her physical theory, for example, this conception is then automatically ruled out as a metaphysical possibility.

However, a philosopher of science may object to this, for as Frisch (2005) shows, many successful and reliable theories like electromagnetism (EM) indeed *are* inconsistent. When interpreted axiomatically, Maxwell's Equations, the Lorentz force law, and energy conservation form an inconsistent set, in the case of modeling discrete charges. Hence, though *cognitively* the class of models in such an instance is open-ended (the physicist happily models away the dynamics of discrete distributions of charges, producing all sorts of fruitful and reliable results) but *logically*, its class of models is empty. To which someone sympathetic to modal rationalism may respond: "Yes, exactly my point. The class *is* empty, these scenarios *are* logically and therefore metaphysically impossible." The fact that such instances of theory-articulation is obviously still *reliable* (it would be hard at present-day to even *imagine* our world, practically speaking, without the discoveries and contributions of Faraday, Lorentz, Maxwell, etc.) plays right into the hands of Van Fraassen—the aim of theories is *empirical adequacy*. On the other hand, a constructive realist like Giere sympathetic to modal rationalism may simply bite the bullet and argue that the class of these cognitive models which obviously demonstrate such empirical success and reliability does *not* entail that they are metaphysically true (let alone being even logically consistent). Indeed, they are not (strictly speaking). Point charges are also a nomological impossibility, as are perfectly rigid rods, etc.

Whether one therefore considers these models as representing 'fallible veracities' (Teller (2004)) or 'convenient fictions' is in the eye of the beholder—gazing upon other issues such as property-realism, nomological skepticism (Cartwright (1999)) and other issues lying outside the scope of this essay. In the main, however, details aside, the issues hinge upon how to tell an 'appropriate' idealization. Plato already reminded us that representation is not duplication, hence the former is always 'false' in *some* sense. Logical consistency, in that regard, though an essential desideratum in many instances, may not ultimately prove itself to be an absolutely necessary condition in

certain contexts—hence Van Fraaseen's claim of empirical adequacy over truth. To which the realist rejoins-reliability in terms of 'saving the phenomena' is neither necessary nor sufficient for truth.

[xliii] As disciplinary specialties within the field of physics, mathematical physics and theoretical physics should *not* be equivocated. They are distinct disciplines, though obviously not disjunct.

[xliv] Recall the metaphysical/epistemic impasse of Kant's antinomies. Not only is the modal gate between epistemic conceivability and metaphysical possibility not excessively wide, but (for Kant) there may be more than one gate that cognition must negotiate! "[T]he…will is…in its visible acts, necessarily subject to the law of nature, and so far *not free*, while yet, as belonging to a thing in itself,…not subject to that law, and…therefore *free*." (Kant, (1781,1965), 28). To invoke my illustration: Modal gate 1 (nomological necessity): "Nope, sorry no free will here. Go to gate 2, maybe they can help you." Modal gate 2 (metaphysical possibility): "Sure, the will is free—but you don't get to know! Go back to gate 1."

[xlv] The choice of connectives here is rather deliberate. The "⊃" is the material conditional: For any *wffs* φ, ψ: φ⊃ψ is *a priori iff* (φ→ψ) is true. (Chalmers (2002), 175)

[xlvi] Consider as an example Railton's (1981) notion of an "ideal explanatory text."