The Verdict's Out:

Against the Internal View of the Gauge/Gravity Duality

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Abstract

The gauge/gravity duality and its relation to the possible emergence (in some sense) of gravity from quantum physics has been much discussed. Recently, however, Sebastian De Haro (2017) has argued that the very notion of a duality precludes emergence, given what he calls the internal view of dualities, on which the dual theories are physically equivalent. However, I argue that De Haro's argument for the internal view is not convincing, and we do not have good reasons to adopt it. In turn, I propose we adopt the external view, on which dual theories are not physically equivalent, instead.

1 Introduction

The gauge/gravity duality has generated much discussion about whether space-time geometry or gravity emerges (in some sense) from quantum physics.[1] Recently, however, De Haro [2017] has argued that the very notion of a duality *precludes* the possibility of emergence given what he calls the *internal view* of dualities, on which dual theories are physically equivalent. In turn, this claim impinges upon the broader debate about whether we can make claims about emergence given a duality. After all, since the internal view of dualities is supposed to *rule out* emergence, any such debate is rendered moot once we adopt the internal view. My goal here, though, is to argue that De Haro's argument for the internal view is not convincing. Instead, I propose we adopt the *external view* of dualities, on which dual theories are *not* physically equivalent.

First, I introduce Fraser's [2017] three-pronged distinction of predictive, formal and physical equivalences, characterizing dualities in terms of this distinction (§2.1). I then make things more concrete by briefly considering the gauge/gravity duality via the Ryu-Takayanagi conjecture from the **AdS/CFT** (anti-de Sitter space/conformal field theory) correspondence (§2.2).

Next, I introduce De Haro's interpretive fork between the internal and external views of dualities (§3). I illustrate how the internal view is supposed to preclude emergence, but criticize De Haro's argument for the internal view – that it is meaningless to hold the external view given 'some form of' structural realism and how the two theories are

[1]One prominent physicist who is a proponent of emergent space-time is Seiberg 2007, while philosophers like Rickles 2011/2017, Teh 2013, and Crowther 2014 have all tackled the topic.

‘totalizing’ in some way – by showing how it does not work without further assumptions (§4). In turn, given the interpretive fork, I propose we adopt the external view instead. In concluding remarks, I briefly discuss this result in relation to the broader debate about emergence within the gauge/gravity duality.

2 Gauge/Gravity through AdS/CFT

2.1 Duality

Fraser [2017] takes two theories related by a duality to have two features: (i) they agree on the transition amplitudes and mass spectra, and (ii) there is a ‘translation manual’ that allows us to transform a description given by one theory to a description given by another theory. We may explicate (i) and (ii) by first considering distinct sorts of ‘equivalence’ proposed by Fraser [2017, 35]:

- *Predictive equivalence*: “there is a map from T_1 to T_2 that preserves the values of all expectation values deemed to have empirical significance by T_1 and that preserves the mass spectra, and vice versa.”

- *Formal equivalence*: “there is a translation manual from T_1 to T_2 which maps all quantum states and quantum observables deemed to have physical significance by T_1 into quantities in T_2 and respects predictive equivalence, and vice versa.”

- *Physical equivalence*: “there is a map from T_1 to T_2 that maps each physically significant quantity in T_1 to a quantity in T_2 with the same physical interpretation and respects both formal and predictive equivalence, and vice versa.”

Given our characterization of a duality as (i) and (ii), we may quite naturally say that two theories are dual to one another when they are *predictively* and *formally* equivalent. Furthermore, supposing that this three-pronged distinction exhausts the possible equivalences relevant to physics, we might also say that two theories satisfying (i)-(iii) are also *fully*, or *theoretically*, equivalent.

Here it would be germane to differentiate two distinct sorts of structures in a duality. Given predictive and formal equivalence, the isomorphism holding between physical and empirical quantities of the dual theories suggests a structure, which may be called the *empirical core* of the duality. However, as Teh [2013, 301] also notes, despite the empirical core, "duality is precisely an equivalence between two theories that describe (in general) different physical structures, i.e. theories with non-isomorphic models." In other words, while there is an empirical core, by which physical and empirical quantities are mapped onto one another, these quantities are generally related to other quantities in a quite different manner on each side, viz. there is 'excess structure' exogenous to the empirical core. Without further argument, we are not entitled to 'discard' this 'excess structure', which also means that predictive and formal equivalence (characterizing the empirical core) does not automatically entail physical, and hence full, equivalence.

Given Fraser's framework, I will briefly introduce the gauge/gravity duality more concrete by briefly examining the example of **AdS/CFT** correspondence.

2.2 The AdS/CFT Correspondence

The *gauge/gravity duality*, or *holographic principle*, postulates a duality between a suitably chosen N-dimensional gauge quantum field theory (QFT) that does not describe gravity, and a quantum theory of gravity in (*N+1*)-dimensional space-time (the 'bulk') with an N-dimensional 'boundary', on which the gauge theory is defined. Hence the slogan: gauge on the boundary, gravity in the bulk.

The **AdS/CFT** correspondence is a specific case of the gauge/gravity duality. On the one hand, '**AdS**' stands for anti-de Sitter space-time - a maximally symmetric solution to the Einstein equations with a constant negative curvature and a negative cosmological constant. More accurately, though, the '**AdS**' in **AdS/CFT** correspondence should be taken to refer to a string theory of quantum gravity defined *on* a 5-dimensional **AdS**. '**CFT**', on the other hand, refers to a quantum field theory with scale (or conformal) invariance defined on the 4-dimensional boundary of the **AdS**. The **AdS**-side theory is defined in the 'bulk', and the **CFT**-side theory is defined on the 'boundary' of the **AdS** space-time.

The **AdS/CFT** correspondence, then, refers to a postulated duality between the two theories, satisfying (i) and (ii) from §2.1. (i) is satisfied given the postulate that bulk fields propagating in the bulk are coupled to operators in the boundary **CFT**. Hence, the **AdS** theory of gravity will predict exactly the 'same physics', viz. transition amplitudes, expectation values and so on, as the **CFT** theory without gravity.

Beyond empirical, i.e. measurable, quantities, physically significant quantities of **AdS/CFT** must also relate to one another since it is a duality. In other words, (ii) is supposed to hold simply as a core postulate. This is not to say that (ii) is completely unfounded: in particular, we have evidence suggesting that at least *some* physical quantities of dual theories are related to one another in surprising ways, which in turn supports the claim that (ii) holds. Here I will focus on one such relation, the Ryu-Takayanagi conjecture.

The Ryu-Takayanagi conjecture postulates that the entanglement entropy of two regions on the boundary is related to the surface area within the bulk:[2]

$$(\mathbf{RT}):\ S_A = \frac{Area(\widetilde{A})}{4G_N}$$

RT tells us that the entanglement entropy of a region on the boundary of the **AdS**, S_A, viz. the von Neumann entropy[3] in the **CFT**, is directly proportionate (by 4 times the Newtonian gravitational constant) to the area of the boundary surface $\widetilde{A}$ bisecting the bulk, dividing the two entangled regions on the boundary. Below, *Fig. 1.* shows a simplified diagram for visualizing **RT**.

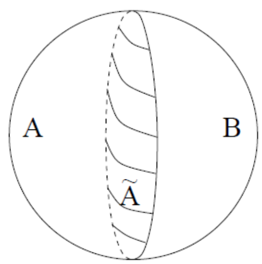

Fig. 1. The area $\widetilde{A}$ bisects the bulk space-time into two, and on the boundaries of the two parts we define the regions A and B. The Ryu-Takayanagi formula tells us that given a change in S_A we get a change in the size of $\widetilde{A}$ by the proportion of $\frac{1}{4G_N}$. [Figure taken from Van Raamsdonk 2010]

RT paints an interesting picture for emergence of space-time geometry from quantum theory: the area of a space-time itself is closely related to quantum entanglement entropy in a surprising way. An increase in the entanglement entropy between two

[2]See Ryu & Takayanagi 2006 for technical details.

[3]The von Neumann entropy is given by $S_A = -Tr(\rho_A log \rho_A)$. The reduced density matrix describing the region A, ρ_A, is obtained from tracing over the B-components of the combined density matrix of A and the entangled region B, ρ_{AB}: $\rho_A = Tr_B(\rho_{AB})$.

regions of a field described by **CFT** leads to a proportionately increasing boundary area of the bulk, and hence a geometric (or gravitational) phenomenon is described in terms of a quantum phenomenon.[4]

Given relations like **RT**, we can also see more clearly how **AdS/CFT** is supposed to satisfy (ii): physically significant quantities, such as 'area' of space-time in the bulk and 'entanglement entropy' between two regions on the boundary, are mapped to one another via suitable equations. Hence, **AdS/CFT** is a special case of the gauge/gravity duality: a theory of quantum gravity on a (N+*1*)-dimensional **AdS** space-time is dual to a **CFT** defined on its N-dimensional boundary.

With the gauge/gravity duality made concrete, let us turn to the interpretive task.

3 The Internal View

Dieks et al. [2015] and De Haro [2017] proposes an interpretive fork for dualities: we can either adopt an internal or external view. De Haro describes the *internal view* as such:

> if the meaning of the symbols is not fixed beforehand, then the two theories, related by the duality, can describe the same physical quantities. [...] we have two formulations of one theory, not two theories. [De Haro 2017, 116]

On the contrary, the *external view* holds that:

> the interpretative apparatus for the entire theory is fixed on each side. [...] On this interpretation there is only a formal/theoretical, but no empirical, equivalence between the two theories, as they clearly use different physical

[4]See Van Raamsdonk 2010 for an excellent summary of this picture.

quantities; only one of them can adequately describe the relevant empirical observations.

Is De Haro's characterization of the external view adequate? The fact that there is no 'empirical' equivalence (what Fraser calls physical equivalence) between two theories does not entail that at most one of them can adequately describe the relevant empirical observations, where one description is 'correct' and the other 'wrong', nor does it entail mutually exclusive physics where only one theory can be correct at any one time. To assume so seems to rule out, by fiat, the possibility of emergence, since emergence relies on *both* theories being in a way adequately descriptive of the world (except one is more 'fundamental' than the other). Hence, taking in account Fraser's framework, I re-characterize the external view as such: it is simply the claim that the two dual theories are *physically non-equivalent* i.e. have distinct physical interpretations, despite formal and predictive equivalence.

Given the interpretive fork, if we are led to forsake the internal view, then we are motivated to accept the external view instead. As such, my strategy here is to show that we should forsake the internal view, and in turn accept the external view instead.

To better understand what the internal view is claiming, I break it down into three constituent claims.

The first claim is that of *theoretical equivalence*: under the gauge/gravity duality, the two theories (e.g. **AdS** and **CFT**) are taken to be simply different formulations of a single theory, describing the same physical quantities despite their obvious differences. As Dieks et al. puts it, 'the two theories collapse into one' [2015, 209-210]. In light of Fraser's framework described in §2.3, this claim means that the gauge/gravity duality, on the internal view, involves the conjunction of predictive, formal and physical equivalences. In other words, beyond a one-to-one mapping (a 'translation manual') of relevant physical quantities and the sharing of all transition amplitudes, mass spectra and other observable predictions, the internal view claims that the two theories also have the *same physical interpretation*. However, as Fraser [2017, 35] notes, "predictive equivalence does not entail formal equivalence, and formal equivalence does not entail physical equivalence." Formal and predictive equivalence cannot entail physical equivalence on their own.

The internal view's claim of theoretical equivalence, then, must require an additional claim of *physical equivalence*, in addition to formal and predictive equivalence: the dual theories are taken to be physically equivalent, and hence have the same physical interpretation. As per §2.1, this would indeed entail theoretical equivalence.

Physical equivalence is in turn justified by a third claim, that the two theories in a duality should be left *uninterpreted*. As De Haro claims above, assume 'the meaning of the symbols is not fixed beforehand'. Then, given formal and predictive equivalence, we have an isomorphism between the dual theories' (now-uninterpreted) 'physical quantities' and numerical predictions, viz. an uninterpreted empirical core. Ignoring the 'excess structure' exogenous to the empirical core, we can then take the empirical core to be representing a single uninterpreted theory, where the now-uninterpreted 'quantities' of each dual theory now refer to the 'places' or 'nodes' of the empirical core's structure. As Dieks et al. (2015) puts it,

> A in one theory will denote exactly the same physical quantity as B [...] if these quantities occupy structurally identical nodes in their respective webs

of observables and assume the same (expectation) values. [Dieks et al. 2015, 209]

Now, given this situation, it might seem plausible to claim that the dual theories are really physically equivalent. Consider **RT**. On the internal view, we are led to say that 'area' really has the same meaning as 'entanglement entropy'. After all, in the theoretical structure that is supposed to matter on the internal view, viz. the empirical core, the two terms are related structurally in the same way to other terms elsewhere (sans a proportional constant). Given that the two theories is also stripped of all prior physical meaning, this structural identity suggests that the 'area' and 'entanglement entropy' are really describing the same quantities, despite their obvious non-isomorphism more generally (e.g. different equations in computing these quantities in their respective theories, the terms involved in calculating them, and so on). In other words, it seems that we are allowed to proclaim physical equivalence on this view.

If we do accept this third claim, we get physical and hence theoretical equivalence, and so the internal view does preclude the possibility of emergence: Theoretical equivalence effectively rules out any account of emergence. If the two dual theories are really just different formulations of one theory, then there is nothing for this new, unified, theory to emerge *from*: nothing can emerge from itself in any interesting way. Subsequently, a duality is supposed to *preclude* emergence on the internal view.

Agreed: physical equivalence entails theoretical equivalence, and theoretical equivalence rules out any sort of emergence. However, are we forced to adopt physical equivalence given the internal view? De Haro himself seems unclear on this point. Note the use of "can" in his characterization of the internal view above: "the two theories, related by the duality, *can* describe the same physical quantities" [2017, 116, emphasis mine]. Are we supposed to believe that physical equivalence *can* hold, or that it *must* hold, on the internal view? In other words, since physical equivalence hangs on the third claim of leaving terms of the dual theories uninterpreted, *must* we adopt the third claim, or is it merely *possible*?

De Haro seems to suggest that theoretical, and hence physical, equivalence *must* hold, since he assumes the two dual theories to be 'two formulations of *one theory*' [emphasis mine]. However, later on, he suggests that physical equivalence merely *can* hold, when he considers an example of leaving dual theories uninterpreted beyond structural relations:

> For what might intuitively be interpreted as a 'length, a reinterpretation in terms of 'renormalisation group scale is now *available*.[5] [De Haro 2017, 116, emphasis mine]

The *availability* of an interpretative stance – in our case of **RT**, of interpreting bulk boundary surface area to be the same physical quantity as entanglement entropy – surely does not entail the *necessity* of the stance. Hence, there are two readings of the internal view: on the weak reading, we take the modal talk – e.g. a reinterpretation being 'available' or how we 'can' describe the same physical quantities – seriously, and on the strong reading we ignore the modal talk completely.

On the one hand, the claim that the internal view precludes emergence is not true on the weaker view. On this view, *if* we assume that the terms on both sides of the duality are uninterpreted, then there is no emergence; *but* this is not forced on us. In turn, this

[5]For context, though unmentioned in this paper, length and renormalisation group scale are also dual quantities in AdS/CFT.

makes the preclusion of emergence merely possible. However, this reading of the internal view does not rule out emergence as De Haro claims. I will thus assume that De Haro intends for us to take the strong reading of the internal view, which does claim that the terms of the both sides *are* uninterpreted.

However, we have not yet seen a compelling reason for accepting the claim that we *have to* see the terms of the dual theories as uninterpreted, and subsequently that physical equivalence *must* hold. *A fortiori* we are not obliged to accept the internal view.

Indeed, something is odd about the argument structure I mapped out: To establish the second claim of physical equivalence, we must establish the third claim, that we must discard anything beyond the empirical core and to leave the terms uninterpreted. However, to justify leaving the terms uninterpreted requires a convincing argument for assuming physical equivalence between the two theories to begin with! Otherwise, we have no reason to simply discard the 'excess' structure and leave the dual theories' terms uninterpreted.

Hence, further arguments are required to establish the third claim. Furthermore, if we discover that this argument is wanting, we shall then have reasons to reject the internal view.

4 De Haro's Argument

De Haro does provide an argument, which runs on the idea that two plausible commitments entails the internal view: the commitment that the dual theories are theories of the whole world in some suitably totalizing manner, and the commitment to "some form of structural realism" [2017, 116].

Let us begin by examining the two commitments. The first commitment implies that dual theories are theories of the whole world, in the sense that they are "both candidate descriptions of the same world" [Dieks et al. 2015, 14]. However, *prima facie* this is not true, since on one hand we have a theory of gravity/space-time geometry, while on the other we have a theory without (not to mention different dimensionalities). How can two theories, one describing something the other does not, both be about the same world? We can try to make this assumption intelligible by taking into account the translation manual between the two theories. Given the translation manual, we can claim that the **CFT** theory without gravity does describe gravity in a way. Consider **RT**: while the entanglement entropy described within **CFT** does not appear to describe space-time geometry *by itself*, the **CFT** plus the translation manual *and* **AdS** (in this case **RT**) *does* describe space-time geometry, albeit in a higher-dimensional space-time. When the entanglement described within the **CFT** changes, the boundary surface area in the **AdS**-side theory with gravity changes as well. Hence, by considering the translation manual given by the duality, the first commitment is made plausible.

The second commitment requires us to adopt some form of structural realism. Structural realism here can be understood loosely, since nothing turns on the particular account of structural realism we employ. Furthermore, De Haro himself does not specify precisely what he means by 'some form of' structural realism. As such, I will likewise adopt a loose notion of structural realism: I understand it to be the view that we should be (metaphysically or epistemically) committed only to the mathematical or formal structure of our theories, and this entails, among other things, that theoretical terms are to be defined in terms of their relations to other places or nodes in this formal structure.

Now, De Haro then claims that the two commitments entail the internal view:

> If [the two commitments] are met, it is impossible, in fact meaningless, to decide that one formulation of the theory is superior, since both theories are equally successful by all epistemic criteria one should apply. [De Haro 2017, 116]

Since he does not flesh out his argument in much detail, I attempt to reconstruct his argument in a plausible fashion: firstly, let us grant the two commitments. Do these commitments commit us to the conclusion that it is meaningless to differentiate between the two dual theories?

Dieks et al. [2015, 209] claims that given the first commitment, "it is no longer clear that there exists an 'external' point of view that independently fixes the meanings of terms in the two theories". However, I must admit I do not see why this is the case: as I explained above, the first commitment only makes sense *if* we understand both theories as having pre-determined meanings, and *then* relating them via the duality/translation manual. In other words, the first commitment is perfectly compatible with the external view.

For the remainder of this paper I focus on the second commitment instead. I think the second commitment *does* entail that differentiating the two theories is meaningless, *only if* we believe that one should be a structural realist (epistemically/metaphysically) only about the empirical core of the duality, discarding the 'excess structure' which made the two theories distinct structures to begin with. In other words, we want to say that this 'excess structure' was not physically significant to begin with: only the empirical core was relevant to physics. It seems that this is required to make sense of the claim that it is 'meaningless' to say that one formulation, e.g. the **CFT** side, is better than the other, e.g. the **AdS** side. If structural realism commits us only to the empirical core of the dual theories, then accordingly there is really only one structure in question. Hence, it is meaningless to ask which structure is better (there is only one). If there is only one structure, then the internal view seems to hold: under a structural realist view, the terms of the dual theories are defined in terms of their places in the structure. Hence, within the empirical core's structure, the different terms of the dual theories really mean the same thing, and hence we get some version of the internal view.

Why should we, even as structural realists, commit ourselves only to the empirical core? The argument seems to me to be an epistemic one: we should believe that the structure relevant to the two theories given the duality must really be common to both theories because, as De Haro claims above, "both theories are equally successful" by all epistemic criteria we apply. If this is true then it seems we have no way of differentiating between the two theories, and the best explanation for this epistemic equivalence is to appeal to their being 'the same' in some way. The only thing in common between the dual theories is the empirical core, so we should take this to be what explains their epistemic equivalence. Everything else (i.e. the 'excess structure') can be discarded, since they are irrelevant differences. As such, structural realism should commit us only to the empirical core.

However, it is not clear that the dual theories are indeed epistemically equivalent. In a naive sense, they are epistemically equivalent if one takes 'epistemic' to be 'empirical' equivalence. Given the duality, i.e. formal and predictive equivalence, it is trivial that the two theories are also 'empirically' equivalent. However, I do not think such a notion of empirical equivalence *exhausts* the epistemic criteria for differentiating between scientific theories. Of course, one main desideratum for scientific theorizing is to provide predictions, descriptions and explanations of phenomena. Beyond that, though, I contend that another desideratum of scientific theorizing is to look for ways to develop better scientific theories, be it a more unificatory theory, a more explanatory theory, and so on.

We see this in play when De Haro discusses the position/momentum duality in quantum mechanics: "this duality is usually seen as teaching us something new about the nature of reality: namely, that atoms are neither particles, nor waves. By analogy, it is to be expected that gauge/gravity dualities teach us something about the nature of spacetime and gravity" [2017, 117]. However, this is only possible *if* the two theories were not epistemically equivalent! If they were epistemically equivalent, then how could we learn anything new from one theory that we cannot already learn from another? If 'area' and 'entanglement entropy' really meant the same thing and had the same physical interpretation, how could we learn something new when we realize that area can be related (via **RT**) to quantum entanglement? Indeed, this criticism extends generally to the internal view: how can we learn anything new from a duality if the dual theories are just the 'same theory', and indeed are *uninterpreted* to begin with? We learn something new when two *different* things are related in a surprising way, *especially* when they are related to other quantities, on each side, in interesting ways; I do not see how we can learn something new when one and the same thing is related to itself.

Furthermore, the two theories are *not* epistemically equivalent when we consider the methodological concerns of physicists, who generally note that the **CFT** is well-understood, while the dual string theory of gravity is not. For example, Horowitz and Polchinski [2009] notes that we only approximately understand the gravitational theory, but the **CFT** has been developed to very precise degrees. Lin points out that:

> A dictionary is reasonably well developed in the direction of using classical gravity to study the **CFT**, but the converse problem how to organize the information in certain **CFT**'s into a theory of quantum gravity with a semi-classical limit is hardly understood at all. [2015, 11]

If both theories are equally successful by *all* epistemic criteria we have, then this situation should not appear. Rather, it seems that scientific practice is of the opinion that the two theories are, in fact, *not* epistemically equal: one is more successful than the other in terms of a variety of criteria, such as precision of calculation, ease of understanding, availability of a non-perturbative analysis, and so on. It is one reason why **AdS/CFT** is such an interesting area of research: it allows us to understand a hard-to-understand theory in terms of an easier-to-understand theory. Unless one is given arguments for why such criteria should *not* be epistemically relevant, the dual theories, I contend, are *not* epistemically equivalent.

Of course, one could assume that the *goal* or *ideal*, when we fully understand the translation manual, is to render both theories equally epistemically successful. However, this presumes that both sides *will* end up being just as easy to compute, or understand, and so on. Of course, if we do discover a more fundamental characterization of *why* the two dual theories are related by the duality as such, e.g. the sort of 'deeper' theory Rickles [2011, 2017] hopes for, then clearly we are entitled to the internal view since this 'deeper' theory will ideally explain why the dual theories, despite their apparent differences, can be seen as different facets of a single theory, just like how special relativity unified electromagnetism and made it plausible to understand both the electric and magnetic fields as facets of the 'deeper' Faraday tensor field. Right now, though, there is no such theory in sight, making this point inadequate for supporting the internal view.

Given the foregoing, it is not clear there is epistemic equivalence: the epistemic argument does not hold. The upshot is that we are not compelled to provide an explanation for why the dual theories are epistemically equivalent to begin with (they are not), and hence we have no need to commit ourselves only to the common empirical core, *even* as structural realists, nor to think that differentiating the dual theories is meaningless.

Recall the oddity I pointed out in §3, though. The claim of physical equivalence hangs on leaving the dual theories uninterpreted, but this latter claim was itself motivated by physical equivalence. It was hoped, then, that the epistemic argument could provide independent motivation for adopting physical equivalence. Given my criticism of De Haro's additional argument, though, the circle returns, and leaves the two claims uncompelling. Hence, we should not adopt the internal view itself. Furthermore, my criticisms suggest that the dual theories are in fact *not* epistemically equivalent, and this suggests that the default stance is one where the two theories are not theoretically equivalent at all. Given the duality, the only way this can be so is to adopt the view that the dual theories are physically non-equivalent; in other words we should adopt the external view instead.

To conclude, given the dialectic set up by the interpretive fork, and the inadequacies of the internal view, I suggest that we adopt the external view instead.

5 The Way Forward

Let me end by commenting on the external view and the broader debate on whether there is emergence given a duality (§1). In §3 we have seen how the internal view precludes emergence simply because there are no two distinct theories to speak of: we merely have two ways of looking at a single theory. This in turn swiftly rules out any talk of emergence. The external view, though, does not rule out emergence quite so easily, and there is some leeway to speak of emergence since we *do* have two distinct theories which are, as Teh noted, generically *not* isomorphic to one another. However, given the formal and predictive equivalences demanded by a duality relation, a duality relation is symmetric, and so there is nothing within a duality that will formally broker the asymmetry between two theories we often associate with emergence. One way to do so, as Teh (2013) suggests, is to introduce a claim of relative fundamentality, i.e. which theory is 'more fundamental' than another, is required to break the symmetry and provide us with the required asymmetry for emergence. While the external view does not entail this, it does not rule it out either. Hence, the external view does not preclude emergence; instead, it directs attention about emergence and duality away from the interpretative fork, onto whether and how one can make claims about relative fundamentality in the context of dualities. Alas, this requires much more attention than I can afford here: I leave it for another day.

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