Are Causal Facts Really Explanatorily Emergent?

Ladyman and Ross on Higher-level Causal Facts and Renormalization Group Explanation

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Abstract

In their *Every Thing Must Go*, Ladyman and Ross defend a novel version of Neo-Russellian metaphysics of causation, which falls into three claims: (1) there are no fundamental physical causal facts (orthodox Russellian claim), (2) there are higher-level causal facts of the special sciences, and (3) higher-level causal facts are explanatorily emergent. While accepting claims (1) and (2), I attack claim (3). Ladyman and Ross argue that higher-level causal facts are explanatorily emergent, because (a) certain aspects of these higher-level facts (their universality) can be captured by renormalization group (RG) explanations, and (b) RG explanations are not reductive explanations. However, I argue that RG explanation should be understood as reductive explanations. This result undermines Ladyman and Ross's RG-based argument for the explanatory emergence of higher-level causal facts.

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1. Introduction

In *Every Thing Must Go*, James Ladyman and Don Ross adopt a broadly neo-Russellian metaphysics of causation. However, contrary to most neo-Russellian philosophers, Ladyman and Ross argue that causal facts are "scale-relative" and "emergent". What is Neo-Russellian metaphysics? Neo-Russellian metaphysics is inspired by Bertrand Russell's view of causation in physics (Russell 1912/13). Russell famously held that fundamental physics teaches us that – contrary to the beliefs of philosophers (of his time) – causal relations are not part of the ontology of fundamental physics. Call this the orthodox Russellian claim. Recently, several Neo-Russellian philosophers have expressed agreement with Russell's view of the ontology of fundamental physics. Neo-Russellians are not persuaded by Russell's more extreme view that causation does not play any role in the sciences at all. They argue that causation is a higher-level phenomenon – that is, causal facts are not fundamental but higher-level facts. Call this claim the Neo-Russellian claim. Neo-Russellians hold that the belief in the existence of higher-level causal facts is primarily warranted by the observation that explanations and predictions in the special sciences successfully refer to higher-level causes (cf. Price and Corry 2007, Ladyman and Ross 2007, Ross and Spurrett 2007, Farr and Reutlinger 2013, Reutlinger 2013). The special sciences include the social sciences, the life sciences, and parts of physics (such as thermodynamics). The special sciences contrast with theories of fundamental physics (such as quantum mechanics, quantum field theory, and general relativity). Ladyman and Ross speak of higher-level causal facts in terms of causal "real patterns" that are described by the generalizations and models of the special sciences. However, Ladyman and Ross's elaborate and exact definition of a real pattern is not relevant for the discussion in this paper (see Ladyman and Ross 2007: 233). Usually, a third widely held claim is added to the Neo-Russellian account: the dependence claim, according to which higher-level causal facts metaphysically depend on (non-causal) fundamental physical facts (cf. Loewer 2007, Woodward 2007). A standard way of spelling out the special status of physics is that non-causal fundamental physical facts are the supervenience base for special science facts, including the non-fundamental causal facts of the special sciences.[2] In sum, a Neo-Russellian believes that the conjunction of the orthodox Russellian claim, Neo-Russellian claim and the dependence claim is true.

The main puzzle that the majority of neo-Russellians aims to solve is this: how can we explain that the orthodox Russellian claim, the neo-Russellian claim and the dependence claim are all true in the actual world? I will refer to this request for an explanation as the neo-Russellian challenge. If a (physical) explanation of why these three claims are true can be provided, then higher-level causal facts are physically kosher facts and the neo-Russellian challenge is met. For instance, one influential strategy of meeting the neo-Russellian challenge is the statistical-mechanical approach (for instance, Loewer 2007).

Ladyman and Ross (2007: chapters 3 and 6) advocate a version of ontic structural realism that explicitly endorses the orthodox Russellian claim and the Neo-Russellian claim. The original twist to Ladyman and Ross's Neo-Russellianism is that the absence of causal facts in physics is compatible with the existence of higher-level causal facts (to which the social and life sciences refer), because the higher-level causal facts are – in a sense to be specified – *emergent* from the non-causal physical facts. Following Batterman (2002), Ladyman and Ross selectively build on Jaegwon Kim's (1999) notion of emergence, which is defined by the following five necessary and jointly sufficient criteria:

1. *Emergence of complex higher-level entities:* systems with a higher level of complexity emerge from the coming together of lower-level entities in new

[2] Alternative ways of spelling out metaphysical dependence are, for instance, the grounding relation (Schaffer 2009) and weak metaphysical emergence (Wilson 2010).

structural configurations.

2. *Emergence of higher-level properties:* all properties of higher-level entities arise out of the properties and relations that characterize their constituent parts. Some properties of these higher, complex systems are 'emergent' and the rest merely 'resultant'.
3. *The unpredictability of emergent properties:* emergent properties are not predictable from exhaustive information concerning their 'basal conditions'. In contrast, resultant properties are predictable from lower-level information.
4. *The unexplainability/irreducibility of emergent properties:* emergent properties, unlike those that are merely resultant, are neither explainable nor reducible in terms of their basal conditions.
5. *The causal efficacy of the emergents:* emergent properties have causal powers of their own—novel causal powers irreducible to the causal powers of their basal constituents. (cited after Ladyman and Ross 2007: 193, original emphasis)

Ladyman and Ross reject the criteria (1) and (2) because these criteria "express commitment to a world that decomposes uniquely into non-overlapping components" – a view that is in contradiction with Ladyman and Ross's account of modal physical structures (Ladyman and Ross 2007: chapter 3). Ultimately, Ladyman and Ross commit to a notion of emergence characterized in terms of criteria (3) and (4), which Ladyman and Ross seem to treat as necessary and jointly sufficient conditions for their concept of emergence.[3] They prefer the label "scale relativity of ontology" over "emergence",

[3] Two clarifications: first, Kim as well as Ladyman and Ross are unclear about whether a fact is emergent or "resultant" if only some but not all criteria for emergence (and, respectively, for reduction) are met – for instance, if one is able to explain but not predict a phenomenon based on lower-level information. Second, Ladyman and Ross do not

because the latter "and all its semantic kin have come to stand for a hopeless jumble of different ideas in different literatures" (Ladyman and Ross 2007: 193). My focus in this paper is exclusively restricted to criterion (4), according to which "emergent properties […] are neither explainable nor reducible in terms of their basal conditions"; I will not address the prediction-based criterion (3). I will refer to the explanation-based aspect of criterion (4) of emergence as *explanatory emergence*; that is, I wish to be uncommitted as to whether "explainable" and "reducible" in criterion (4) are identical.

The criterion of explanatory emergence can be applied to causal special science facts as follows: causal facts of the special science are *explanatorily emergent* (and, by the same token, exist relative to a scale) iff these facts *cannot* be explained solely on the basis of "lower-level information" about the interaction of the components of special science systems.[4] On the other hand, causal facts are *explanatorily reducible* (and, synonymously, do *not* exist relative to some scale) iff these facts *can* be explained on the basis of "lower-level information" about the interaction among the components of special science systems. If some special science fact is explanatorily reducible, I will also describe this by saying that there is a *reductive explanation* of this fact (see Hüttemann and Love 2011 for an elaborate account of reductive explanation in physics and the life sciences, which specifies further constraints for reductive explanations).

Moreover, note that facts may be explanatorily emergent and still have a scientific explanation; such facts may have a *non-reductive* scientific explanation. Ladyman and Ross claim that the causal facts of the special sciences are explanatorily emergent and

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address metaphysical emergence, in which, for instance, non-reductive physicalists are interested (Loewer 2009, Wilson 2010).

[4] I assume that Kim's formulations such as "the coming together of lower-level entities" (criterion 1), "properties and relations that characterize their constituent parts" (criterion 2), "lower-level information" (criterion 3), "basal conditions" (criterion 4), and "basal constituents" (criterion 5) are merely stylistic variations of talk about interactions between the components of a system.

these facts are explained in a non-reductive way.[5] Ladyman and Ross's main argument for the emergent character of higher-level causal facts is based on Batterman's (2000, 2002) interpretation of renormalization group (henceforth, RG) explanations:

> Batterman argues that the properties and kinds picked out by universality classes (for example, renormalization groups in mechanics) are 'emergent', despite the fact that Kim's emergentist doctrines (1), (2), and (5) do not apply to them. The existence of the physical explanations for the universalities must, for a naturalist, block any temptation to try to reduce away the emergent kinds and properties through the introduction of 'metaphysical hidden variables'. (Ladyman and Ross 2007: 204)

Ladyman and Ross claim that if causal facts of the special sciences and fundamental physical facts are connected by renormalization group explanations, then causal special science facts are explanatorily emergent, because RG explanations are non-reductive explanations.

Let me add two clarifying remarks: *first*, RG explanations shed light on a particular feature of causal facts: many special science facts (including causal facts) are multiply realized by lower-level facts (see Fodor 1997 as a *locus classicus*), or, to use a technical term from the physics literature, causal facts of the special science are *universal* (I will return to the concept of universality in section 2). This kind of explanation does not explain *all* interesting features of causal facts. For instance, it does not address the feature of causal time-asymmetry. The latter feature, Ladyman and Ross (2007: 251-252) identify, without argument, with the arrow of entropy. Although this is a controversial claim

[5] Note that Ladyman and Ross's arguments for the orthodox Russellian claim are independent of whether RG explanations are reductive explanations (cf. Ladyman and Ross 2007: sections 5.1 and 5.3).

(Frisch 2007), I will grant for the sake of the argument that Ladyman and Ross are able to explain causal time-asymmetry in this way.

Secondly, Ladyman and Ross (2007: 238) are aware of the fact that RG methods do not provide a general explanatory gloss of how the special sciences are connected with fundamental physics (cf. Strevens 2002); rather RG methods induce restricted understanding of inter-theoretic relations among fundamental and non-fundamental physical theories. Although Ladyman and Ross are cautious, they emphasize that RG explanations are a tool of central importance to understanding the relation between fundamental physics and the special sciences:

> Batterman (2002, 143) doubts that we'll often be able to explain rigorously special science universalities in the way we explain physical ones, because 'the upper level theories of the special sciences are, in general, not yet sufficiently formalized (or formalizable) in appropriate mathematical language.' We are more optimistic. There are ongoing efforts both to discover and to explain universalities in the formalized of the social sciences, economics. (Ladyman and Ross 2007: 204-205)

It is difficult to argue against an optimistic attitude, but it seems fair to say that the scope of RG explanations is (presently) limited. To say the least, Ladyman and Ross believe that RG explanations are a paradigmatic case illustrating how (a) fundamental physics and the special sciences are connected, and that (b) special science facts are explanatorily emergent. I will focus on the question whether one is justified to call RG explanation non-reductive explanations, whenever these explanations apply.[6]

[6] Ladyman and Ross (2007: section 1.5) also present arguments against (i) (ontological and epistemic version of) reductionism as the correct characterization of the way fundamental physics and the special sciences are related, against (ii) a particular

In this paper, my main claim is that RG explanations of (the universality of) higher-level causal facts do not support the claim that higher-level facts are explanatorily emergent. I will argue that RG explanations are reductive explanations and, hence, their explananda are not explanatorily emergent. My argument undermines Ladyman and Ross's claim that causal facts are explanatorily emergent. More precisely, I, first, introduce how RG explanations of universal behavior work (section 2). Then, in section 3, I present an argument to the conclusion that RG explanations are reductive explanations. I conclude, in section 4, that Ladyman and Ross cannot use renormalization group explanations in order to support their claim that causal facts of the special sciences are explanatorily emergent (that is, scale-relative).

2. RG Explanation of Universality

In this section, I outline how an RG explanation works. The discussion here will be largely non-technical as the paper is concerned with a non-technical question (I mostly follow the exposition in Batterman 2000).

RG explanations are intended to provide understanding of the puzzling and highly non-trivial fact that the macro-behavior of condensed matter systems with many micro components is – in some circumstances – largely independent of the micro-behavior in the sense that the macro-behavior is universal. Macro-behavior is universal if the same macro-behavior can be realized by microscopically different systems. *Universality* is a technical term used in the physics literature – the more familiar philosophical term for the phenomenon is, at least for the purpose of this discussion, *multiple realizability* (Fodor 1997). One prominent example in the recent literature consists in microscopically different physical systems (such as various gases and magnets) that display the same macro-

mereological account of part-whole relations in fundamental physics, and against (iii) the commitment to existence of a fundamental level of reality. However, these arguments are beyond the scope of this paper.

behavior when undergoing phase transitions (Batterman 2000, 2002). Scientists and philosophers alike believe that the universality of macro-behavior cries out for an explanation: how can we explain the remarkable fact that there is universal macro-behavior?

A paradigm candidate of such an explanation is the RG method that enables us to explain why it is the case that microscopically different systems display the same macro-behavior when undergoing phase-transitions (for instance, gases, fluids and magnets). The guiding idea of RG is to ignore various microscopic details and interactions that are irrelevant for the macro-behavior in question. RG is a general explanatory strategy to distinguish relevant and irrelevant micro-details.

Batterman's prime examples of universal behavior are phase transitions in fluids, gases, and magnets (prominently discussed in Batterman 2000, 2002, 2010). His main focus is on explaining the surprising fact that materially different systems (various gases, fluids, magnets) display the same macro-behavior when undergoing phase transitions (for instance, transitions from a liquid to a vaporous phase, and transitions from a ferromagnetic to a paramagnetic phase near the critical temperature). If microscopically different systems (for instance, fluids and magnets) display the same macro-behavior when undergoing phase transitions, then "sameness" is characterized by the same critical exponent (a dimensionless number, cf. Batterman 2000: 125-126). The explanandum of interest is this sameness in character of macro-behavior.[7]

It is useful to understand the workings of RG explanations of universality in terms of three explanatory elements: firstly, system-specific laws governing the interactions among the micro-components of a physical system (Hamiltonians); secondly, renormalization group transformations; and, thirdly, the flow of Hamiltonians. Let me

[7] I do not discuss whether there is a general model of explanation of scientific explanations that subsumes RG explanations. I think that Woodward's (2003: 220-221) and Strevens's (2008: 179-180) notions of counterfactual dependence and difference-making can be extended to cover RG explanations (cf. Reutlinger 2014).

present these elements in slightly more detail (as indicated above, I am not able to do justice to the elegant mathematical details of RG in this short paper; see Batterman [2000: 137-144] and Fisher [1982: chapter 5] for a detailed survey.)

First step: Hamiltonians

RG methods explain the universal macro-behavior of gases and fluids by representing the physical system in question using a Hamiltonian – a function characterizing, among other things, the interactions between the components (or degrees of freedom[8]) of the system. One specific epistemic problem with the Hamiltonian of a 'real' physical system undergoing phase transition (say, a heating pot of water) is that each component of such a system does not merely interact with its nearby neighbors but also with distant components. Hence, keeping track of the interaction between all the components of, say, a liquid undergoing phase transitions is – because of the large number of components – epistemically intractable.

Second step: Transformations

The second element of the RG explanans deals with this epistemic intractability: a particular transformation on the Hamiltonian (the "renormalization group transformation"; henceforth, RG transformation). Batterman describes the purpose of this kind of transformation as

> […] chang[ing] an initial physical Hamiltonian describing a real system into another Hamiltonian in the space [of possible Hamiltonians]. The transformation preserves, to certain extent, the form of the original Hamiltonian so that when the thermodynamic parameters are properly

[8] Wilson (2010) provides a detailed discussion of the concept of degrees of freedom.

> adjusted (renormalized) the new renormalized Hamiltonian describes a system exhibiting similar behavior. (Batterman 2000: 126-127)

Operations such as spatial contraction and the renormalization of parameters that are involved in RG transformations allow one to represent one and the same fluid F in a different way: the number of interacting components of F (or degrees of freedom) is effectively reduced. That is, the transformed Hamiltonian of F describes the interaction of fewer components (or fewer degrees of freedom). The transformation redefines the characteristic length, at which the interactions among the components of the system at issue are described. Repeatedly applying RG transformations amounts to a description of the system, say fluid F, on larger and larger length scales; the RG transformation is a coarse-graining procedure.[9] Carrying out the transformation repeatedly comes with an epistemic benefit:

> […] the transformation effects a reduction in the number of coupled components or degrees of freedom within the correlation length. Thus, the new renormalized Hamiltonian describes a system that presents a more tractable problem and is easier to deal with. By repeated application of this renormalization group transformation the problem becomes more and more tractable […]. (Batterman 2000, 126f)

In other words, the RG transformation solves the epistemic problem of intractability (see above). Essentially, RG-transformations eliminate micro-details irrelevant for the explanation of phase-transitions.

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[9] Shimony (1993: 208) discusses RG transformations and their applicability conditions in detail.

Third step: Flow of Hamiltonians

Using Batterman's terminology, suppose we start with the "initial physical manifold" or, equivalently, the "real physical" Hamiltonian H of a fluid F (undergoing a phase transition near the critical temperature). Then one repeatedly applies the RG transformation and obtains other Hamiltonians describing the same system F with fewer component interactions than H. Interestingly, these different Hamiltonians "flow" into a fixed point (in the space of possible Hamiltonians), which describes a specific behavior characterized by a critical exponent (Batterman 2000: 143). Now suppose there is another fluid F* and its behavior (during phase transition) is described by the initial Hamiltonian H*. Repeatedly applying the RG transformation to H* generates other, equivalent Hamiltonians (with fewer component interactions than H*). If the Hamiltonians representing fluid F* and fluid F turn out to "flow" to the same fixed point, then their behavior, when undergoing phase transition, is characterized by the same critical exponent (Fisher 1982: 85; also Batterman 2000: 143).

Hence, we have arrived at the explanandum of an RG explanation: the three elements of an RG explanation provide a method to determine under which conditions two microscopically different systems (that is, systems with different initial "real physical" Hamiltonians) belong to the same "universality class", i.e. are characterized by the same critical exponent (Fisher 1982: 87). Two systems belong to the same universality class, if reiterating RG transformations reveals that both systems "flow" to the same fixed point.

Batterman has a point when he claims the RG method explains by showing how various details about component interactions are irrelevant for the macro-behavior of systems (Batterman 2000: 127). RG explanations do not merely reveal what is irrelevant but also provide information about what is relevant for a specific macro-behavior.

To sum up, this is, essentially, how Batterman thinks that RG explanations of universal behavior work. I have no ambition to challenge his exposition. The main question I will address in the remainder of the paper is whether any of the three elements of an RG explanation warrants our interpreting RG explanations as reductive explanations (see section 1). I argue that it is justified to interpret RG explanations as reductive.

3. RG Explanations as Reductive Explanations

Ladyman and Ross adopt Batterman's (2002) interpretation of RG explanations of universality; Morrison (2012) argues in favor of emergence on similar grounds. This interpretation is a key premise for their argument to the conclusion that higher-level causal facts are explanatorily emergent. The core claim of Batterman's interpretation is that RG explanations are not reductive explanations. Following the terminology introduced in section 1, an explanation is not reductive iff a fact about a composite system S (e.g., a fluid or a magnet) is not explained in terms of the components of S (e.g. molecules and electrons). Ladyman and Ross present the following argument: (1) if the universality of causal special science facts can be explained by an RG explanation and if RG explanations are not reductive, then universality is explanatorily emergent. (2) The universality of causal facts of the special science facts can be explained by an RG explanation and RG explanations are not reductive. (3) Therefore, the universality of special science causal facts is explanatorily emergent. I will argue that this argument is not sound, because RG explanations are – contrary to Ladyman and Ross's view – explanatorily reductive explanations. That is, premise (2) of the argument is false. This claim, if indeed true, does not merely oppose Ladyman and Ross's view, but also Batterman's and Morrison's claims that the successful application of RG explanations supports emergentist claims.

Let me start with two intuitions that might lead someone to think that RG explanations are not reductive explanations. The claim that universality cannot be explained reductively strikes me as true in two readings of "reductive", which are not relevant for my positive account.

Firstly, RG explanations are not reductive in being standard mechanistic explanations that focus on a *system-specific* micro-mechanism producing the macro-behavior of the system (Machamer et. al 2000, Craver 2007). For instance, RG explanations of universality do not aim to explain why a certain kind of fluid F displays a certain kind of critical macro-behavior just by appeal to the interactions of the components of a fluid F. It also is not the case that we are able to explain universality by identifying the *same* causal mechanism being operative in fluids and magnets. If it were the case that universal behavior could be explained by appeal to a common mechanism that is active in different systems, then we would have a micro-mechanistic causal explanation of universality (for instance, the same mechanism for photosynthesis is instantiated in different species of trees explaining the presence of photosynthesis in these different species). This is not so in the case of universality at issue. The *explanandum* of an RG explanation is the fact that *two (or more)* systems with different components and different interactions between these components show the same macro-behavior (when undergoing phase transitions). For this reason, an explanation of universality obviously requires information that goes beyond the system-specific causal mechanism in a particular kind of physical system (a kind of gas, say). Therefore, it is evident that RG explanation cannot be reductive in virtue of referring to a single system-specific lower level mechanism.[10] As I will argue below, this does not imply that RG explanations cannot be reductive (in the required sense, see below).

Second, Batterman holds that RG explanations are not reductive in the sense that all the details of the interactions among the components are explanatorily relevant.

[10] Hüttemann and Love (2011: sect. 3) require that reductive explanation draw on components that are "intrinsic" to the system whose behavior is to be explained. Since the explanandum of an RG explanation concerns macroscopic similarities between two (or more) microscopically different systems, the requirement of intrinsicness has to be amended: the reductive explanation of macroscopic similarities between two microscopically different systems is reductive if it refers to components that are "intrinsic" to the systems (and do not belong to the environments of the two systems).

Batterman's main argument runs as follows: typical reductive explanations are mechanistic explanations. According to the causal-mechanistic model of explanation, reductive explanations do not and cannot ignore causal "micro details" because an explanation provides "detailed causal-mechanical accounts of the workings of the mechanisms leading to the occurrence of the explanandum phenomenon" (Batterman 2000: 28). A causal-mechanical explanation "tells us all of the gory details" (ibid.) about why a particular effect occurs (Batterman 2010: 2, 21). However, ignoring certain details about the interactions of components of a physical system is essential for the second element of the RG explanation (that is, the RG transformations). Batterman concludes that the causal-mechanistic model of scientific explanation cannot accommodate RG explanations.

However, Batterman's characterization of the causal-mechanical model – that is, not being able to ignore details about the interactions of components – is inaccurate as a general characterization. This characterization applies only to a specific version of the causal account (such a Railton's account, to which Batterman [2002: 28] alludes). In contrast to Batterman's view, a number of recent influential causal-mechanical models of explanation are explicitly designed to account for the fact that many excellent mechanistic scientific explanations "ignore details". For instance, Strevens (2008) and Franklin-Hall (ms) explicitly deny that explanation merely consists in citing all the details about causal processes and micro-mechanisms; they add an "optimizing procedure" (Strevens) and a "biggest bang-for-your-buck" principle (Franklin-Hall), which are procedures to omit irrelevant causal information about causal micro-mechanisms. Woodward's (2010) notion of causal specificity plays a similar role in his theory of causal explanation; it determines the accurate explanatory level of abstraction and the choice of variables. Moreover, even a neuro-scientific micro-mechanistic explanation of long term potentiation refers to the activities of neurons but abstracts from various physical details without losing the micro-mechanistic character of the explanation (Craver 2007: 65-72). These examples support the claim that it is compatible to explain by citing causes and micro mechanisms and, at the same time, to ignore details. Hence, Batterman's key claim that the causal-mechanistic model of explanation cannot account for explanations that involve abstractions from details is *either* controversial (to say the least), *or* Batterman's argument induces a merely verbal dispute regarding whether the cases – which Craver, Franklin-Hall, Strevens, and Woodward discuss – deserve to be called (causal-mechanistic) reductive explanations. The point I wish to make is that an explanation may be reductive and it may also ignore causal micro details. (Let me add a clarification: I defend the claim that RG explanations are *non-causal* explanations [cf. Reutlinger forthcoming]. However, this claim about the non-causal character of RG explanations is independent of the question whether they are reductive explanations.)

In sum, I grant that RG explanations are not reductive in the sense that such explanations work by citing a micro-mechanism or by counting all the details about interaction among components as explanatory. The interesting question I want to answer is whether there is another interesting way in which RG explanations are reductive.

RG explanations are reductive in the simple sense introduced in section 1: a reductive explanation allows us to derive the explanandum (for instance, why fluid F and magnet M exhibit the same critical behavior, represented by the critical exponent) from information about the components of fluid F and magnet M. To see why, let me show that all three steps of an RG explanation appeal to the components of systems undergoing phase transition. The first step deals with representations (that is, Hamiltonians) of large systems of interacting components. It is characteristic of the relevant Hamiltonians that they describe the components of systems undergoing phase transitions such that each component of such a system does not merely interact with its nearby neighbors but also with distant components. The second step is concerned with transformations of these representations. Transformed Hamiltonians describe systems with reduced degrees of freedom, but the Hamiltonians nonetheless describe interactions between the components of liquids and magnets. The third step finally tells us why systems with different initial Hamiltonians show the same macro behavior: if the Hamiltonians representing, say, fluid F and F* turn out to "flow" to the same fixed point, then their behavior, when undergoing phase transition, is characterized by the same critical exponent. The second and the third step allow us to ignore details about the interactions, but ignoring details does not amount to the fact that interactions among the components do not matter at all and the associated Hamiltonians are not explanatory. It is a more accurate interpretation to say that RG methods show that universality depends on few details about the interactions among components. RG explanations are reductive because they determine the universality class of, say, fluids F* and F by calculating the critical exponent of each fluid from the (repeatedly transformed) Hamiltonians, which represent interactions among components. As it turns out *few details* about component interactions (or, equivalently, degrees of freedom) matter for the explanation at issue, but this is not important for deciding whether RG explanations are reductive or not. What is more, such a 'reductive' interpretation of RG explanations is perfectly compatible with the fact that, unlike standard micro-mechanistic explanations, RG explanations of universality do not proceed by identifying system-specific interactions among components (that is, a system-specific mechanism). To sum up, it is natural to say that RG explanations are reductive because the three steps of RG explanations make indispensable use of modeling the interactions among the components of physical systems (Norton [2012] and Hüttemann et al. [forthcoming] advocate similar views).

At this point, one might object that RG explanations are not reductive because they are not 'micro' explanations. That is, one might wonder whether RG explanations are indeed reductive explanations, if reductive explanations are required to describe explanatory patterns on a microscopic length scale.[11] In order to respond to this concern, it is useful to draw on Norton's few/many distinction of different kinds of *reductive* explanations in physics (Norton forthcoming: section 4.2). According to Norton, the label "reductive explanation" is ambiguous and there are two significantly different kinds of reductive explanations: (a) reductive explanations that refer to *few* interacting micro components, and (b) reductive explanations referring to *many* interacting micro components. Norton argues that the reductive statistical mechanical explanation of the ideal gas law is of the first kind as it refers to few components of an ideal gas in the following sense:

> A single molecule can be treated as a gas, albeit one with wildly fluctuating properties. Nonetheless one can determine the mean values of these fluctuating quantities, such as the gas' mean density and the mean pressure it exerts. These mean quantities can be scaled up from the few component level to the level of the very many components of a macroscopically sized samples of a gas of non-interacting molecules. What results is the ideal gas law. (Norton forthcoming: 14)

There is a second type of reductive explanation, which does not appeal to "few" components but to a large system consisting of *many* interacting components. Norton holds that RG explanations are reductive explanation of the "many" type:

> We cannot scale up the properties of a single component molecule or spin and recover phase transition behavior. Something more is needed. […] The advance of renormalization group methods was to realize that analyzing the

[11] Thanks to a referee and to Margie Morrison for raising this point.

> fluctuation behavior of systems of *very large numbers of components* is essential to representing phase transitions, quantitatively. (Norton forthcoming: 15; emphasis added)

I agree with Norton (forthcoming: 15) that RG explanations are of this second type of reductive explanations. RG explains universal macro behavior in terms of the behavior of many micro components with their associated Hamiltonians plus RG transformations and the flow of Hamiltonians to a fixed point. The relevant lesson from Norton's distinction, here, is that RG explanations are *not* reductive in virtue of describing few components on a microscopic length scale (hence, Norton "few" reading does not apply). Rather, RG explanations are reductive in accord with Norton's "many" reading: they explain by filtering out the relevant features of the interactions of many components. RG explanations apply to systems with many interacting components, and it is, interestingly, the case that not all of the details of these interactions between many components are explanatorily relevant.

Where does the result that RG explanations are reductive leave us? This result undermines Ladyman and Ross's claim that if the universality of special science causal facts is RG explained, then causal facts of the special sciences are explanatorily emergent or, to use their own terminology, scale-relative. In fact and contrary to Ladyman and Ross's claim, the *explananda* of RG explanation turn out not to be explanatorily emergent, as these *explananda* have reductive scientific explanations. Recall that Ladyman and Ross advocate a concept of emergence, according to which a fact about a system S is emergent iff this fact about S cannot be (a) explained and (b) predicted on the basis of information about interactions among the components of S (see section 1). I refer to criterion (a) as explanatory emergence. I conclude that one necessary condition for being emergent (that is, explanatory emergence) is not met in the case of RG explanations.

I anticipate two additional concerns regarding the reductive interpretation of RG explanations.

First, one might be concerned that RG explanations cannot be reductive since they involve taking the thermodynamic limit (Batterman 2002, Morrison 2012). The role of limit theorems ("asymptotic reasoning") in RG explanations is a controversial issue, but I believe that the non-reductive character of RG explanations does not depend on the outcome of this controversy. If Batterman (2000) and Morrison (2012) are right, then RG explanations involve an ineliminable idealization about the micro components of, say, gases, magnets and fluids: the idealized assumption is that a system undergoing phase transitions has infinitely many interacting components. If this view turned out to be true then, on my view, RG explanations would be highly idealized reductive explanations. Certainly, this strong idealization – if indeed indispensable – raises pressing interpretational questions, but even if RG explanations are highly idealized this fact does not contradict the claim that these explanations are reductive in the sense described above. On the other hand, if Butterfield (2011), Norton (2012), and Hüttemann et al. (forthcoming) are right, then the idealization in question is not indispensable, because it is possible to approximate the results of the idealized model by using a model that is not idealized (as the latter assumes big but finite physical systems). In this case, RG explanations are reductive and work without the idealization in question, as Butterfield, Norton, and Hüttemann et al. happily admit. Hence, both approaches to the role of limit theorems are compatible with the reductive character of RG explanations. The real point of controversy, on which the opposing views disagree, should not be described as a quarrel about the reductive character of RG explanations: the disagreement concerns (a) whether RG explanations do in fact require the idealization in question or not, and (b) whether such an idealization (if indeed indispensable) raises problems for the credibility of RG explanations or not (cf. Earman 2004).

Second, Morrison argues that RG explanations of universal behavior cannot be reductive, because the fact that a kind of macro behavior is universal fails to supervene on the micro-level (i.e. the interactions among components). Morrison argues as follows:

> The dependence relation required for supervenience is clearly lacking in cases of universal behavior since fixing the subvenient properties in no way fixes the supervenient ones and vice versa: the whole is substantially different from the sum of its parts. In cases of supervenience, any change in higher-level properties requires a difference in lower-level properties, something that fails to occur in cases of emergence. […] The claim so often associated with supervenience – there can be no A difference without a B difference (where A properties supervene on B properties) – is irrelevant here since once the system reaches the critical point and universal behavior (A properties) is dominant, information about micro-level structure (B properties) is simply lost. (Morrison 2012: 164-165)

Morrison argues that belonging to a certain universality class U does not supervene on having a particular micro-structure S, since (a) S does not fix being a member of U, and (b) there can be a difference in U without a difference in S. However, both claims (a) and (b) seem to be false in the context of RG explanations of universality (cf. Hüttemann et al. forthcoming).

Let me turn to claim (a) first. Contrary to Morrison, RG explanations show that a system having a particular micro-structure S (represented by a Hamiltonian) determines the fact that this kind of system belongs to a universality class U. The RG explanation is a tool that makes us understand which aspects of S matter for belonging in class U. More precisely, RG explanations enable us to understand two things: (i) they reveal that systems with different micro-structures (represented by different ‘initial’ Hamiltonians) belong to the same universality class (e.g. fluids and magnets). (ii) RG explanations also show that and why some systems with different micro-structures in fact belong to different universality classes. Batterman describes this latter case as follows:

> For instance it turns out that that the critical exponent can be shown to depend on the spatial dimension of the system and on the symmetry properties of the order parameter. So, for example, systems with one spatial dimension or quasi-one dimensional systems such as polymers, exhibit different exponents than (quasi-) two dimensional systems like films. (Batterman 2000: 127)

Both (i) and (ii) are compatible with supervenience, since a supervenience claim does not entail that every change in the subvenient facts results in a change of the supervenient facts.

Let me now discuss claim (b): Morrison suggests that the principle ‘no difference in the supervenient facts without a difference in the subvenient facts’ is not satisfied in the case of universality. This is not the case, because if two physical systems belong to different universality classes, then the systems differ, for instance, with respect to the “spatial dimension of the system and on the symmetry properties of the order parameter” (Batterman 2000: 127). A difference, for instance, in spatial dimensionality is accompanied by a difference on the level of the components.

To summarize the response to Morrison’s supervenience worry, the fact that a physical system belongs to universality class U supervenes, contrary to Morrison’s claim, on the particular interactions among the components of this systems, because (a) facts about the interacting components ‘fix’ to which universality class the system in question belongs, and (b) systems belonging to different universality classes exhibit some difference in their micro-structure. Therefore, it is not the case that – as Morrison argues – RG explanations fail to be reductive explanations, because supervenience does not hold (granting that supervenience is required for reductive explanations). However, it is not merely the case that RG explanations are compatible with supervenience but, rather, RG methods are illuminating scientific explanations that provide us with understanding of *why* universal behavior supervenes on micro-structure.

4. Conclusion

I started out with Ladyman and Ross's innovative version of Neo-Russellian metaphysics (section 1), which falls into three claims: (1) there are no fundamental physical causal facts (orthodox Russellian claim), (2) there are higher-level causal facts of the special sciences, and (3) higher-level causal facts are explanatorily emergent. While accepting claims (1) and (2), I attacked claim (3). Ladyman and Ross's argument for the claim that higher-level causal facts are explanatorily emergent is based on the premise that certain aspects of these higher-level facts (i.e. their universality) can be captured by renormalization group (RG) explanations and, following Batterman's interpretation of RG explanations, the assumption that such explanations are not reductive explanations. After presenting how RG explanations work (in section 2), I argued, in section 3, that RG explanation are reductive explanations in that the *explanandum* is derived from 'simplified' information about the interaction of the components of different physical systems (for instance, from the transformed Hamiltonians of fluids and magnets). This result undermines Ladyman and Ross's RG-based argument for the explanatory emergence of higher-level causal facts.

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