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CONTRIBUTED PAPER

The Open System View and the Metaphysics of Symmetries

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Abstract

Philosophers have been drawing their attention to the metaphysics of symmetries. Most have taken a Closed System View, that is, the metaphysical assumption that closed systems are ontologically fundamental. In this article, I explore the consequences of adopting a different perspective, the Open System View, according to which open systems are regarded as ontologically fundamental. I argue that by doing so, our metaphysical understanding of symmetries changes substantially in three respects: Epistemic approaches are favored, ontic approaches should change the set of physical symmetries regarded as fundamental, and the metaphysical connection between conservation principles and symmetries is weaker than thought.

1. Introduction

Most physicists and philosophers have for a long time held the view that closed systems have a special status. It has been widely assumed that closed, isolated physical systems not only play a privileged methodological (or even epistemic) role but also have a primary role in ontology. Even though this overarching "philosophy of closed systems" has sometimes been challenged by some (see Bhaskar 1975; Cartwright 1983, 1999; also, Zurek 2003; Schlosshauer 2004), in general, it is an integral part of the pivotal assumptions in the philosophy of science, physics, and the metaphysics of science. In a recent yet unpublished paper, Michael Cuffaro and Stephan Hartmann (2024) want to turn this tide by defending what they call "the Open Systems View." The essence of their view is to argue that open systems are *more fundamental* than closed systems, sailing against a long-standing tide. They do not claim that closed systems do not exist in any sense or that the Closed System View is absolutely mistaken. They circumscribe themselves to rescue open systems from a derivative, secondary place in physics and philosophy, seeking to honor their importance in epistemology, methodology, and ontology.

I am sympathetic to this "philosophy of open systems." Yet, I believe that it also has far-reaching, unexplored-yet consequences that can look a bit radical for many. In particular, the adoption of an Open System View would imply a series of revisions and reassessments of philosophical and metaphysical quarrels in the philosophy of physics and metaphysics that deserve further attention and deeper exploration. I cheer the Open System View, and I suggest here that we should also cherish some of its radical consequences. The claim that open systems are more fundamental than closed systems, perhaps, invites us to see long-standing problems with new, fresh lenses. And perhaps it provides us with new responses.

In this article, I do not defend the Open System View, but I take it as a departing point. I am rather interested in showing how it may reconfigure and shake the grounds of some relevant philosophical claims and debates. That is, I am interested in some of its radical implications. In particular, I focus on the metaphysical status of symmetries. There has been a growing trend in physics and philosophy that has regarded physical symmetries (e.g., space-time symmetries, gauge symmetries, permutation symmetries, among others) either as aspects of the fundamental ontology (Heisenberg 1975; Weinberg 1987; Baker 2010; French 2014; Schroeren 2020) or as guides to the fundamental ontology (North 2009, 2021; Baker 2010; Dasgupta 2016; Allori 2019). This has led to questions about the metaphysical status of symmetries and their importance for ontological inquiry. I argue here that, to a good extent, this problem has presumed a Closed System View. Under an Open System View, the conceptual bases of the debate radically change. It has consequences for whether ontic views of symmetries can be solidly defended, for which would be the real symmetries of the dynamics of fundamental systems (now open systems), if any, and for which kind of relations symmetries would have with, for instance, conservation principles.

2. The closed system versus the open system views

The distinction between open and closed systems is very well-known in physics. While closed systems are those that do not interact with other systems (i.e., there is no exchange of matter, information, or energy with external systems), open systems are those whose interactions with external systems (i.e., with their environment) cannot be neglected because they substantially affect the dynamics of the target system. Even though it is widely acknowledged that genuine closed systems cannot really be obtained in nature or the laboratory (because of, for instance, the pervasive influence of gravity), their theoretical and mathematical treatment is relatively straightforward and has shown impressive heuristic and methodological advantages when building up physical theories or modeling physical systems. Few would doubt the usefulness of closed systems.

But, the dispute between Open System and Closed System *views* is not over the usefulness, importance, or even the existence (in some sense) of both open and closed systems. The dispute is about their relative fundamentality from epistemic, methodological, and ontological perspectives. Closed System View's (many) supporters rapidly recognize that many physical phenomena require modeling systems as open systems (e.g., in the case of adding dissipation, as in Heisenberg–Hubbard spin chains, the Ising model, and cold-atom systems; other examples relate to magnetic resonance and the decay of unstable atoms). Similarly, Open System View's (scarce) defenders also recognize that closed systems are methodologically and epistemically useful for the simplification of dynamical problems, to single out quantities or regularities of interest, and so forth. The bone of contention revolves around whether closed systems are *more fundamental* than open systems. Of course, the word "fundamental" is perhaps ambiguous as it has different meanings in different contexts, but as Cuffaro and Hartmann argue, the Open System View is ambitious in its scope because Open Systems would be fundamental *tout court*: epistemically, methodologically, and, more important for my purposes here, ontologically fundamental (see Cuffaro and Hartman 2024, sec. 4).

Besides "fundamental," the other keyword here is "view" (or, more generally, a "philosophy"). A view is associated with (1) a set of *methodological* assumptions so as to build models in a framework or theory, to characterize their objects, their relations to other objects, and so forth, and with (2) a *metaphysical* attitude with respect to the nature of those objects (in particular, which are considered fundamental, which ones secondary, etc.). In short, a view articulates the means and strategies to formulate physical theories and build up models and how they relate to the ontology of the physical world. My focus here is on (2), the ontological assumptions. The first thing to be stressed is that ontological fundamentality refers to the place that an entity, property, relation, or structure occupies in one's ontology. Views, per se, do not have an ontology, but theoretical frameworks or models do have it. The view rather conveys an overarching metaphysical declaration that certain entities, properties, relations, or structures have such-and-such nature across different theoretical frameworks or models. The Closed and Open System views convey such a declaration in terms of the fundamentality of closed or open systems, respectively, across different theoretical frameworks and models.

The concept of *ontological* fundamentality has been very much disputed (see Schaffer 2003, 2009; Correia and Schnider 2012; Koslicki 2012; Tahko 2018; McKenzie 2022). Cuffaro and Hartman (2023, sec. 4.1) cash out the idea of ontological fundamentality in terms of how different theoretical frameworks represent their objects and what they acknowledge as fundamental (or essential), even if their metaphysical assumptions differ. I believe that a more straightforward and general way to characterize ontological fundamentality for closed and open systems is in terms of their dynamics. In the Closed System View, modeling an open system's dynamics consists of basically showing how a coupling arises from the interactions of originally closed systems. Because the target of physical laws is closed systems, the dynamics of open systems is *deduced* from the behavior of closed systems plus their interactions. That is, open systems' dynamics does not explain nor constitute closed systems' dynamics, but rather the other way around. Nor is open systems' dynamics the target of our fundamental laws, but it derives from them that primarily apply to closed systems. In this sense, closed systems can be said to be "more fundamental" than open systems.

It is now a bit clearer in which aspects the Open System and Closed System views disagree—they hold different methodological assumptions and different metaphysical attitudes concerning the place that open systems occupy. As I said before, in what follows, I am not concerned with the methodological aspects but only with the metaphysical. So, I reduce both views to the following theses:

CSV Thesis Closed systems are ontologically more fundamental than open systems.

OSV Thesis Open systems are ontologically more fundamental than closed systems.

This basically means that the dynamics of open systems, according to the OSV Thesis, is not dependent on a coupling between two systems, nor is it derived from fundamental laws plus "perturbations" from the environment, but it is primitively open and involves the interactions with the environment in the very equations that govern the evolution of the target system (for a defense of the open systems' autonomy, see Ladyman and Thébault 2024).

As I have previously suggested, the *spirit* of the Open System View (or of an "Open System Philosophy") is not new. Nancy Cartwright (1983, 1999) has also advocated for a similar view in criticizing the universality and fundamentality of laws of nature. She illustrates this point, for instance, by the behavior of a one-hundred-dollar bill falling at St. Stephen's Square in Vienna on a windy day. Fundamentalist and universalist approaches to laws of nature cannot explain this behavior to a good extent because they depend on a Closed System View. Roy Bhaskar (1975) also criticizes the emphasis on closed systems to the detriment of open systems in science. He says that the traditional philosophy of science faces a dilemma when confronted by open systems: either it has to sacrifice the universal character of the lawlike generalizations or the empirical status of them (Bhaskar 1975, 55). This spirit has also made its mark among physicists. Some have complained about an imbalanced emphasis on closed systems. Wojciech Zurek, one of the leading physicists in decoherence theory, says that "the idea that the 'openness' of quantum systems might have anything to do with the transition from quantum to classical was ignored for a very long time" (Zurek 2003, 717). Maximiliam Schlosshauer, in a more general vein, says: "[S]cience has established the idealization of isolated [closed] systems, with experimental physics aiming at eliminating any outer sources of disturbance as much as possible in order to discover the 'true' underlying nature of the system under study" (Schlosshauer 2004, 1273).

Even though the spirit of an Open System Philosophy has been in the air for a while, it is clearly a disrupting philosophy with few advocates. Most problems and solutions in different branches of the philosophy of science, the philosophy of physics, and the metaphysics of science presume, in one way or another, that closed systems are what we should exclusively look at. What would happen if we shifted the focus to the Open System View? Cuffaro and Hartman give some hints of problems that can benefit from this. I want to be more radical, however. If we shifted the focus to the Open System View, the bases of many problems and solutions in these areas of inquiry would be shaken. In what follows, I focus on one of the remarkable consequences of adopting an Open System View: the problem of the metaphysical status of symmetries.

3. Ontic versus epistemic approaches to symmetries

In the last decades, philosophers have increasingly drawn their attention to physical symmetries. There are good reasons for this. Symmetries in physics have not only been crucial for theory building, modeling, and empirical research but they also seem to be essential for ontological inquiry. Some physicists and philosophers have claimed that (some) physical symmetries are aspects of the fundamental reality, or even stronger, underly a "logic of nature" (see Heisenberg 1975; Weinberg 1987; Baker 2010; French 2014; Schroeren 2020; see Martin 2002 and Lopez 2024a for criticisms). Others have seen physical symmetries as premises to infer what the fundamental ontology is like (see North 2009, 2021; Baker 2010; Dasgupta 2016; see Lopez 2023 for criticisms). Of course, the philosophical discussions about their methodological and ontological status are complex, and there are plenty of alternative positions. Even their conceptual interpretation is under dispute (see Redhead 1975; Nozick 2001; Brading and Castellani 2003; Belot 2013; Dasgupta 2016, among others).

As for symmetries' metaphysical status, two camps can be distinguished (in a very broad sense): Those who believe that physical symmetries are *ontic* (or real) and those who believe that they are *epistemic* (or unreal) (see Brading and Castellani 2007; Livanios 2010; Lopez and Esfeld 2023). According to ontic (or realist) approaches, "[S] ymmetries are real aspects of the world usually taken to be properties of the world (or of its structure) or second-order laws concerning the form of physical first order laws" (Livanios 2010, 296). The thesis can be stronger by promoting symmetries to be fundamental aspects of the world from which particles, fields, and the macroscopic world emerge. In opposition, epistemic (or antirealist) approaches consider that "the presence of symmetries in physical theories is related to general conditions of physical knowledge or to some limits inherent in our way of describing the physical world" (Livanios 2010, 296). In a similar vein, Cristian Lopez and Michael Esfeld (2023) also assume an epistemic approach in a Humean framework: "Symmetries are metalaws in the sense that they are 'laws of the laws' . . . but perform a heuristic, epistemic role in the simplification, systematization, and unification of the true generalizations within the best system" (2024, 9).

My thesis is that the Open System View substantially changes the basis on which the debate about the metaphysical status of symmetries has unfolded by adding new ingredients to ponder. Most physical symmetries of philosophers' interest (i.e., spacetime symmetries, gauge symmetries, permutation symmetries, and some discrete symmetries such as charge conjugation, parity, or time reversal, among others) can only be found in highly idealized models that describe the behavior of *closed* systems. When (nonconservative) interactions are taken into account, most of these symmetries break down and can only be recovered by enlarging the system and forming a new, bigger, closed system. So, the new ingredient is this one: Relevant physical symmetries hold only in closed systems. Ontic views then seem to crucially depend on assuming that closed systems are, at least, more fundamental than open systems. But, if we rather assume an Open System View, ontic views lose some grip. The debate on the status of symmetries then not only depends on our interpretation of symmetries but also on the place of closed and open systems in one's ontology.

Let me give an easy example. In Hamiltonian classical mechanics, the Hamiltonian of a two-particle system is

$$H = \frac{p_1^2}{2m_1} + \frac{p_2^2}{2m_2} + V(q_{1,}q_2) \tag{1}$$

The state of the system is given by the generalized coordinates q_i and the conjugate momenta p_i, with $i = 1,2$. The trajectory in the phase space (i.e., the time evolution of the state) is given by the Hamilton equations. The Hamiltonian of the system, it is worth stressing, is all that needs to be known to have complete information about the changes over time in a closed system. For closed systems like this one, time-translation symmetry has been used as an argument to conclude that the structure of time in Hamiltonian classical mechanics (and any theory that is time-translation invariant) is homogeneous. Time translation (τ) it basically means to move our target system in time by changing the temporal instants of the initial conditions

$$\tau : t \to t + t_0 \tag{2}$$

A Hamiltonian system is time-translation invariant if it is the case that

$$H(q_i, p_i) = \tau(H(q_i, p_i)) \tag{3}$$

Naturally, whether time-translation symmetry holds or not depends on the form of the Hamiltonian and if it has some explicit dependence on time. But the form of the Hamiltonian for closed systems has no explicit dependence on time as the potential $V(q_i)$ is time-independent. To put it differently, the question of time-translation invariance of the Hamiltonian (eq. 3) is simply asking if H explicitly depends on time, in this case, if the potential V depends on time. For closed systems, there is no such time dependency, in general. Then time-translation invariance holds and H remains constant (that is why time-translation invariance goes hand-in-hand with energy conservation). It is, however, easy to imagine a situation in which H does depend on time. For instance, it is enough to make V in (1) to explicitly depend on time $V(q_{1,}q_2, t)$. Then, it is easy to imagine a situation in which the target system (now open) interacts with an external potential that, for instance, fluctuates randomly in time. In these cases, the dynamics of the target system is no longer invariant under time translation because the energy of the system will vary depending on the intensity of the time-dependent potential. In consequence, the Hamiltonian of the target system will not be constant either.

Those who believe that symmetries are ontic are prone to think that time-translation invariance is part of the fundamental reality (in particular, it is a property of time's structure). But they believe so because they exclusively focus on closed systems. In the preceding case, the solution is to enlarge the system of interest so as for it to involve the original target system and the environment. This new, bigger closed system recovers time-translation invariance, despite the fact that the target system (now an open subsystem) is not. From the Closed System View, realists about symmetries have an appealing argument with which to grip. Closed systems are deemed ontologically fundamental. Time-translation invariance (or any other space-time symmetry in general) is a feature of the dynamics of closed systems. Therefore, time-translation invariance is a symmetry of the fundamental systems (in Hamiltonian mechanics). From here, it is easy to conclude that some physical symmetries, such as time-translation invariance, are ontic and fundamental. Also, the assumption of time-translation invariance has been extremely successful when building physical theories, which might suggest a sort of Nonmiracle Argument. The benefits extend even beyond as this implies that, for instance, energy must be conserved for closed fundamental systems.

If we, however, adopt an Open System View, this argument and all its attractive consequences no longer go through. To begin, closed systems are not fundamental.

The dynamics of closed systems is no longer the subject matter of physics; then, it is not important to elucidate the symmetries of the fundamental systems, which are now open systems. It is the open systems' dynamics that are now the subject matter of physics, and it is, in general, not symmetric under time translation (or under other space-time symmetries, too). So, why should we regard time-translation invariance as ontic, or stronger, fundamental? In other words, time-translation invariance is not part of the dynamics of fundamental systems anymore because it is no longer part of the dynamics of open systems. The fact that closed systems are time-translation invariant does not have metaphysical weight. And this could mean that epistemic approaches score a point here. After all, closed systems are just idealizations, mathematical constructs. We arrive at their symmetries by "shielding" systems from their environments; we deduce their dynamics from open systems. Their symmetries are idealizations mathematical constructs, too. But this is just part of the epistemic, heuristic, and methodological resources of our physical theories, not part of the real world. Then, they are probably not ontic but epistemic.

I know this is not a knock-down argument against ontic approaches. After all, they could simply endorse the Open System View and commit themselves to a different set of symmetries (those that open systems' dynamics do instantiate). I will say something about this shortly, but I believe, in any case, that the Open System View would reshape many aspects of the debate. It lays the ground for interesting arguments on behalf of the epistemic camp. After all, many physical symmetries would just suffer the same fate as closed systems. This resembles Cartwright's argument against universalism and fundamentalism in laws of nature: (Some) symmetries lie just as much as laws do.

4. If ontic, which ones?

As I have said before, defenders of ontic approaches to symmetries can accept the Open System View. But, the problem now is that the set of physical symmetries that are ontologically fundamental can be quite different with respect to the usual ones in the literature. The Open System View forces us to look at the symmetries of the dynamics of open systems, not of closed systems. Therefore, which symmetries are ontic

(or, stronger, aspects of the fundamental reality) crucially hinges upon which is the dynamics of the fundamental ontology: Closed or open systems? Even though the technical details are complex, the argument is straightforward. Let me illustrate this argument in quantum mechanics.

In nonrelativistic quantum mechanics, the evolution of pure quantum states (i.e., closed systems) is generated by Hermitian Hamiltonians. The dynamics of the quantum-time independent state for a closed system is, as is well known, the Schrödinger equation. In general, Hermitian operators are classified by 10-fold internal symmetry classes, which are based on time reversal, charge conjugation, and chiral transformation (see Dyson 1962; Kawabata et al. 2023). But *open* quantum systems are coupled to external systems (i.e., their environment) and are described by non-Hermitian Hamiltonians. Non-Hermicity substantially changes the nature of the symmetries since non-Hermitian operators are no longer classified by 10-fold but by 38-fold internal symmetry classes (see Kawabata et al. 2019, 2023).

Regardless of whether some of the symmetries of closed systems can be preserved (or recovered) in the classes of symmetries of open systems, this result alone introduces some degree of metaphysical underdetermination in the debate. In the Closed System View, ontic symmetries in the 10-fold internal symmetry classes are more fundamental than the 38-fold internal symmetry classes of open quantum systems. But in the Open System View, it is the other way around, and 10-fold symmetries should be considered special cases. So, the classes of symmetries that an ontic approach to symmetries is committed to strongly depend on the metaphysical attitude that is adopted, either the Closed System or the Open System view. The metaphysical underdeterminacy that arises here does not come from the physics or the mathematics of open or closed systems but from the overarching philosophical view that is adopted with respect to their places in one's ontology.

5. Open systems: Symmetries and conservation principles

The last important consequence of the Open System View I would like to stress is the status of conservation laws. In this case, the point mainly concerns formal aspects. There is abundant literature in the field that explores the links between conserved quantities and symmetries. I do not get into details here, but it is widely held among philosophers that Noether's first theorem ties together symmetries and conserved quantities (see Brading and Brown 2003; Read and Teh 2022). In essence, Noether's first theorem affirms that for every smooth and continuous symmetry of the action of a physical system, there is a conservation law (which delivers a conserved quantity). However, it is important to stress that the theorem only holds if the action of the system does not involve dissipative forces (e.g., the system is closed). Even though Noether's theorems were formulated for classical cases, there is a quantum analog to Noether's first theorem. For closed, unitary systems, an explicitly time-independent observable, say J, is a conserved quantity if and only if it commutes with the Hamiltonian (a paradigmatic case is the angular momentum of the hydrogen atom). It is possible hence to generate a continuous symmetry ($U = exp(i\phi J)$) That leaves the Hamiltonian invariant. Therefore, for unitary, *closed* systems is possible to get biconditional statements for the conservation of J in time ($\dot{J} = 0$), a continuous symmetry of the system ($[J, H] = 0$), and the symmetry of the Hamiltonian ($U^{\dagger} HU = H$). This recovers Noether's theorem's spirit. So, if the Closed System View is adopted, then these theoretical connections between symmetries and conserved quantities in closed systems hold good.

Yet, the treatment of these connections in open systems is different. To begin, the correspondence between continuous symmetries and conserved quantities is broken for open, dissipative systems (or nonunitary systems in quantum theory) (see Baumgartner and Narnhofer 2008; Buca and Prosen 2012; Albert and Jiang 2014). To put it differently, symmetries and conserved quantities are, in general, independent in the cases of open, dissipative systems. This drastically reduces the conceptual benefits of symmetry-based analyses of conserved quantities. Open quantum systems are represented by (reduced) density operators that generally evolve according to the Liouvillian (or Lindbladian), $\mathcal{L}$, a superoperator defined by

$$L(\rho) = -i[H,\rho] + \sum\nolimits_m L_m \rho L_m^{\dagger} - \frac{1}{2}\left\{L_m^{\dagger} L_m, \rho\right\} \quad (6)$$

Where the L_m are dissipators that describe the dissipative coupling to the external environment, H is the (Hermitian) Hamiltonian operator, and ρ is the (reduced) density operator. It is worth emphasizing that in the physics and the formalism of open quantum systems, the Lindblad master equation is the main dynamical equation.

$$L(\rho) = \frac{d\rho}{dt} \quad (7)$$

The relevant symmetries of open quantum systems are, therefore, the symmetries of the Liouvillean. What happens in these cases is that many of the relations between conserved principles and symmetries are lost. For instance, there would be conserved quantities whose symmetry generators do not commute with $\mathcal{L}$ but are conserved as a whole. That is, from a conserved quantity a symmetry cannot be inferred (without conditions). Or a continuous symmetry generator could fail to match a conserved quantity. It is then not always the case that a symmetry implies a conservation principle (for technical details, see Albert and Jiang 2014). From the Closed System View, these results are as expected as conceptually uninteresting. After all, Noether's theorems are interesting because they speak about connections at the level of fundamental laws (i.e., those of closed systems). So, it is not a serious problem if they cease to hold at a nonfundamental level. But, from the Open System View, these results are remarkable: At the fundamental level, the connection between symmetries and conservation principles is much weaker than thought. The subject matter of physics does not capture the same connections. Too many ontological considerations to these connections might be unwarranted as they are overall absent in the fundamental (open) systems. These connections, the argument might go on, are construed as merely mathematical devices, valid only for ideal systems. This does not imply that these connections cease to exist. They are there, but in the closed systems' dynamics. They can be epistemic and methodologically crucial for doing physics. The point of the Open System View is that they are not central anymore; the view turns the ontology around by promoting open systems to what is fundamental and closed systems to what is derivative. The connections, therefore, lose their metaphysical interest when it comes to ontology.

6. Conclusions

In this article, I have shown some of the consequences of endorsing an Open System View when it comes to the debate on the metaphysical status of symmetries. I have argued that the debate has commonly adopted a Closed System View, in which the symmetries of the dynamics of closed, fundamental systems have greatly been viewed as the only relevant ones. Yet, if an Open System View is adopted, open systems are now regarded as fundamental. Then, their symmetries (or the lack of them) are now to be taken more seriously. Pursuing this line of reasoning further, I have shown that epistemic approaches could have an advantage over ontic approaches, that ontic approaches could be committed to a different set of symmetries than the usual one, and that the connection between symmetries and conservation principles could be weaker than thought.

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