CHAPTER 1

The Genealogy of Thomas Kuhn's Metaphysics

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1.1 Introduction

In his *Structure of Scientific Revolutions* (SSR) of 1962, Thomas Kuhn famously stated: "In a sense that I am unable to explicate further, the proponents of competing paradigms practice their trade in different worlds" (SSR-2, p. 150).

More than twenty years later, Kuhn came back to this topic and asked: "Is this an idealist position? Perhaps it is. But the idealism is then unlike any other of which I am aware" (Kuhn 1984, p. 122).

Probably for most of his readers who are critical of that position, the novelty of his idealism will not be true solace. Also, the following sentence will not change the critical readers' mind: "Perhaps it is an idealist's world nonetheless, but it feels very real to me" (Kuhn 1984, p. 123).

In fact, quite soon after the publication of SSR, Israel Scheffler reacted in a way that was highly influential for the further philosophical reception of Kuhn's position: "I cannot, myself, believe that this bleak picture, representing an extravagant idealism, is true" (Scheffler 1967, p. 19).

The problem seems to be that realists do not understand how any idealism can present the world – that is seen by idealism as mind-dependent – as real.

In this chapter, I will not really argue for Kuhn's metaphysical position. An argument only makes sense if one knows what one is arguing for. Kuhn's metaphysical position is, however, rather elusive, of which Kuhn was aware. Therefore, I will try to make Kuhn's position better intelligible. Perhaps I will also be able to contribute some initial plausibility, similar to the "reasonable suspicion" that justifies further investigation of a legal case. For that purpose, I shall put Kuhn's attempted metaphysical position into a larger historical context, its genealogy. I shall begin with two developments that proved of utter significance for Western thought: first, the Copernican revolution

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(Section 1.2) and, second, the distinction between primary and secondary qualities (Section 1.3). Both items figure fundamentally in the emergence of modern physics. The Copernican revolution especially played a major role in Kant's critical philosophy, because it transported the specific post-Copernican mode of thought into philosophy. However, the distinction between primary and secondary qualities is also relevant in this context, for in order to make the idealist components of Kant's critical philosophy more digestible, it may be formulated in terms of that distinction (Section 1.4). The next step in this genealogy will be twentieth-century physics, because in both special relativity theory and quantum theory, a post-Copernican element can be found (Section 1.5). Finally, we reach Kuhn and can, in the light of the earlier developments, articulate his position as belonging to the given genealogy (Section 1.6). My hope is that this will make Kuhn's attempted metaphysical position more accessible, especially to those who, when reading "world change" and similar expressions, quickly turn away in hardly veiled contempt.[1]

1.2 Copernicus

The starting point of the genealogy of Kuhn's metaphysics is the Copernican theory of the planetary system.[2] Copernicus suggested that the Earth is not at the center of the planetary system, but the Sun is. This has important consequences for our understanding of the observable motions of all celestial bodies. For my purposes, it is sufficient to discuss the motion of the Sun. In the geocentric view, the motion of the Sun was real and objective: It was causally efficacious, and a property solely of the Sun. There was no difference between the objectivity and reality status of, for instance, the radiation of the Sun and the Sun's motion in the sky; both were seen as undoubtedly real and causally efficacious.

In some sense, nothing in the causal efficacy of the motion of the Sun has changed in the meantime. For instance, the motion of the Sun generates the difference between day and night, and not moving your sunshade according to the Sun's motion may cause a real sunburn, which may not be an apparent one. It seems that producing causal effects is a *sufficient*

[1] For a recent attempt to defend Kuhn's world change talk by a historical case study, see Wray and Andersen 2019.

[2] I am giving here an extremely simplified version of the Copernican theory that abstracts from everything that is not relevant in our context. For more responsible versions that include aspects of the complicated historical development of the theory, see, e.g., Andersen, Barker, and Chen 2006, pp. 130–163; CR.

indicator of something being real.[3] It also seems impossible that something unreal, that is, not existent, can generate causal effects. The geocentric worldview was just completely natural in the sense that it identified something in the heavens that had effects on the Earth as real, including the motion of the Sun. This is also in full accordance with a general stance of ancient and medieval philosophy and science to see the real as completely object-sided, as independent and devoid of any components that have their origin on the subject side. This is, of course, also our everyday view of reality: Real in the relevant sense[4] are the things that stand opposite to us, that are completely independent of us, and that have, as I shall express it, no components that have their origin at the subject side ("genetically subject-sided components" for short; "genetically" does not refer to "genetics," but to "genesis"). Thus, in our common understanding we speak very naturally of reality as "mind-independent."

In this view, the following equation holds:

> real = objective = purely object-sided = without genetically subject-sided components.[5]

Given this view of reality, it is completely intelligible and plausible that any form of "idealism" in metaphysics appears to be incoherent and thus not even worth discussing. Most generally, any form of idealism seems to claim that something genetically subject-sided is at least part of, or even fully constitutes, reality.[6] To someone committed to the above view of reality, this is incoherent, because by "reality" we just *mean* the completely object-sided, to which the epistemic subject does not and cannot contribute anything whatsoever.

[3] The close connection between reality and causal efficacy has been called the "Eleatic principle" by David Armstrong, following a passage in Plato's *Sophist*; see, e.g., Colyvan 1998, p. 313 with fn. 1. I wish to thank Howard Sankey for making me aware of the expression "Eleatic principle."

[4] The relevant sense here covers things that are located outside of us. Of course, also in our everyday understanding we know about the reality of events or processes that are located in our consciousness, like feelings. In the text, I am only referring to external reality because the fundamental subject here is the natural sciences.

[5] Note especially that in this equation "objective" and "purely object-sided" coincide. This is a consequence of the fact that our language is adapted to (commonsense) realism. The attempt to articulate philosophical positions different from realism therefore meets linguistic difficulties, which is why I distinguish "objective" from "purely object-sided"; otherwise one can only speak in paradoxes. I have introduced and used the terms "subject-sided" and "object-sided" earlier in Hoyningen-Huene 1993, pp. 33–36, 45–47, 62–66, 122 fn 283, 125, 267–271; Hoyningen-Huene, Oberheim, and Andersen 1996, p. 139; Hoyningen-Huene and Oberheim 2009, p. 208.

[6] I am aware of the fact that "absolute" or "objective" idealists would not agree with this characterization of idealism because they would deny that the respective entity, spirit or nous or whatever is in any useful sense subjective. This is, however, not important in our context.

Now, Copernicus claims that the Sun's observed motion in the sky is an "apparent" motion in contrast to the "true" (or "real" or "own") motion. In fact, as the Sun is at the center of the planetary system, it may be said that the Sun is at rest. The daily apparent motion of the Sun from sunrise in the East to sunset in the West is generated by the Earth's rotation and, because we cannot sense the Earth's rotation, by the projection of this rotation onto the sky. More generally, the motions of all celestial bodies are "apparent motions," consisting of two components. One component is the true motion, for instance, in the case of the planets, their motion around the Sun. The second component is added to the first one. It results from our point of view on a rotating and Sun-orbiting Earth. The addition of these motion components results in the apparent motion of the respective celestial body, that is, the motion of the celestial body as it appears to us observers on the Earth. The case of the Sun is particularly simple because the Sun's own motion is zero, so in the course of a day we only see the projection of the Earth's rotation onto the sky, which results in an (approximately) uniform motion of the Sun in the sky. In the case of the planets, however, their apparent motion is at times quite unexpected, namely retrograde. In antiquity, this gave rise to complicated constructions of epicycles and various other devices in order to "save the phenomena," that is, to account for the supposedly real motions of the planets.

Now, it seems completely natural to call the observed motion of the Sun and of the other celestial bodies "objective." There is no phenomenological difference between the objectivity of the observed motion of a horse that passes by and the observed motion of the Sun or the Moon in the sky. Different observers agree on these motions, these motions are thus intersubjectively observable, and they can be consistently measured by physically very different devices to very high degrees of accuracy. All this contributes to the impression that these motions are independent of any contributions by the observer and thus objective and real.

However, under a Copernican analysis, the observed motion of a planet and of other celestial bodies contains both genetically *object*-sided contributions (the planet's own, "true" motion) and genetically *subject*-sided contributions (the projection of the Earth's rotation and motion onto the planet's observed motion). Several features of this situation are noteworthy.

First, the observable motion of a celestial body is a *phenomenologically* inextricable mixture of the projection of Earth's rotation and motion, and the true motion of the respective body. For instance, no analysis of a planet's trajectory alone can reveal *that* there are genetically subject-

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sided contributions involved, let alone distinguish the genetically subject-sided components from the genetically object-sided ones.

Second, the phenomenological indistinguishability of genetically subject-sided and object-sided contributions to the apparent motion is reflected in classical physics by the fact that they can be treated mathematically in identical ways. In the calculation of the apparent motion, the subject-sided contribution is vector-added to the object-sided contribution in the same way as two purely object-sided motion components would be vector-added.[7]

Third, apparent motions are no indicators whatsoever of the true motions; in fact, taken singly, they are completely misleading about the true motion. The reason is that the observer's motion is entirely independent of the true motion of the object, and it can overwhelm the true motion component of the apparent motion. For instance, in the case of the Sun, its apparent motion across the sky is absolutely no indicator of its true motion, namely zero motion. (This does of course not exclude the possibility to calculate the true motion once the apparent motion and the observer's motion are known.)

Fourth, the phenomenological equivalence of genetically subject-sided and object-sided contributions to apparent motions immediately extends to its causal effects. In order to avoid a sunburn, one has to move one's sunshade, independently of whether the Sun's observed motion is, in the Copernican sense, only apparent or true. This is why the geocentric planetary system was historically so stable. Only if one puts the planetary motions into a larger theoretical context and adduces data *beyond* planetary position data does the superiority of the heliocentric system become intelligible.

The Copernican system clearly has had massive substantial consequences for planetary astronomy. I believe, however, that its methodological consequences exceed the substantial ones by far. In fact, arguably the Copernican insights represent the most important turning point in the history of Western scientific and philosophical thought. In antiquity and the Middle Ages, the way natural phenomena presented themselves as purely object-sided was basically accepted as veridical. Of course, our senses may deceive us from time to time, and the phenomena presented to us may not be the ultimate reality, as most famously Plato thought.[8] And

[7] The deeper reason for this symmetrical treatment of a projected motion and the true motion is that Newtonian physics is Galilei invariant.

[8] Here is a fundamental difference between Plato's and Copernicus's figures of thought. In his allegory of the cave, Plato distinguishes between shadows – the analogue to the phenomena we have access to – and true things (ideas), to which we have no access. In this setting, the shadows are at least indicators of true things, even if the shadows do not represent them truthfully. The analogue does not hold in the Copernican case.

of course, Aristarchus of Samos already in antiquity considered the possibility that the Sun is at the center of the planetary system. But by and large, natural phenomena were seen as purely object-sided, as our commonsense realism also suggests.

Now the fundamentally disruptive insight of Copernicanism is that real, objective, causally efficacious phenomena that *appear* to be purely object-sided *are not* necessarily purely object-sided, because they may contain genetically subject-sided components. Whether that is true of a particular case and what the genetically subject-sided components possibly are cannot be discovered by investigating the phenomenal qualities of the phenomenon alone, but only by putting it into a larger theoretical context. In other words, what is real and objective *and thus* appears to be purely object-sided may in truth contain genetically subject-sided contributions, that is, components that in some sense stem from us. And most importantly, this is not just a *philosophical* speculation, but a *scientific* insight that proved immensely successful in its application to planetary theory in the Copernican system. Without considering the possibility that objectively determinable orbits of celestial bodies may nevertheless contain genetically subject-sided contributions, the Copernican system could not have been invented. The identification of genetically subject-sided components in some set of phenomena is scientifically of utmost importance, because they have to be investigated separately from and in a different way than the genetically object-sided contributions.

The analysis of an *earthly* phenomenon may be useful to further illustrate the properties of the planetary case. In 1851, French physicist Léon Foucault mounted a 67-meter-long pendulum in the dome of the Panthéon in Paris. Once the pendulum is set in motion, the plane of its motion does not stay stationary, as one would expect from everyday experience or from the law of the conservation of momentum. In fact, the plane of the pendulum's motion rotates due to the Earth's rotation; relative to the Sun, it stays stable due to conservation of momentum. This motion is causally efficacious, as is demonstrated by many installations of Foucault's pendulum, where the pendulum displaces small objects once they are reached by the rotating plane of motion and the pendulum knocks them over.[9] Again, this is a phenomenon fulfilling all criteria of objectivity, and still, it has massively genetically subject-sided components.

[9] For a demonstration of the effect, see, e.g., www.youtube.com/watch?v=iqpV1236_Q0 (accessed September 25, 2019).

The consequences of Copernicus's discovery of the difference between apparent and true motions have had dramatic consequences for Western scientific and philosophical thought, until today, because it conveys a fundamental lesson that has been taken very seriously in science ever since. Any phenomenon fulfilling all tests of its reality such as object-sidedness, resistance, robustness, and causal efficacy may still contain genetically subject-sided components that cannot be discovered by analyzing the qualities of the phenomenon itself. These genetically subject-sided components may come to the fore if the phenomenon is embedded in a larger theoretical context. Most importantly, this insight was not the result of philosophical speculation but was the essential ingredient of a fundamental and extremely successful revolution in astronomy, which was ultimately accepted because of the pressure of empirical data. The same critical thought that was at the bottom of Copernicus's dramatic innovation was also at the bottom of the equally dramatic innovation of physics in the seventeenth century. Galilei, Boyle, Descartes, and others, who were the fathers of this revolution, made a distinction similar to the Copernican distinction between apparent and real motion. It rested on the same insight: that something apparently purely object-sided and objective may in truth contain genetically subject-sided components.

1.3 Primary and Secondary Qualities

As the Copernican planetary system had its predecessors in antiquity, so was the distinction between primary and secondary qualities already made in antiquity by the atomists Leucippus and Democritus.[10] In comparison to the philosophical thought of Plato and Aristotle, their effect on the development of science and philosophy was firstly rather meager. Because in the beginning of the modern phase of science corpuscularism was the dominant metaphysics, problems and answers with some similarity to their ancient analogues emerged again. All the main contributors to the emergence of modern physics such as Galilei, Descartes, Hobbes, Boyle, Locke, and Newton discussed and used some version of the distinction between primary and secondary qualities.[11] For the purpose of this chapter, I do not have to consider different variants

[10] The historical situation is, in fact, much more complicated; see, e.g., Lee 2011.

[11] See Alexander 1974; Ayers 2011; Burtt 1932/1980, pp. 83–90, 115–121, 130–134, 180–184, 231–239; Campbell 1980; Curley 1972; Keating 1993; Martinez 1974; McCann 2011; Palmer 1976.

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because they roughly agree about what I need here as their fundamental aspect.[12]

Primary qualities were thought of as inherent qualities of the respective object. In the seventeenth century, the mostly agreed-upon examples were the object's geometrical shape, its size, or its motion. By contrast, secondary qualities of an object were qualities that resulted from the interaction of the object with our senses. The most agreed-upon examples were the object's taste, odor, color, sound, or heat. As in Copernicus's case of apparent motions, secondary qualities are no substantive indicators of the content of primary qualities. This is because primary and secondary qualities stand in many-many relations: The same set of primary qualities can generate different secondary qualities in different circumstances, or in different observers, and the same secondary quality can be generated by different sets of primary qualities. For instance, the same phenomenological red can be generated by light consisting of one wavelength or of various mixtures of different wavelengths. Thus, it is impossible to infer from some secondary quality alone anything about the underlying primary qualities.

The fundamental importance of the distinction between primary and secondary qualities derives from the fact that primary qualities were the subject matter of the emerging mathematical physics, whereas secondary qualities were not. Thus, the delineation of the subject matter of the emerging modern physics was given by the distinction between primary and secondary qualities. The distinction in a sense neutralized those qualities that did not seem to be amenable to a mathematical treatment, that is, the secondary qualities. The distinction pushed them, together with their messiness in comparison with the mathematical crispness of the primary qualities, out of the domain of physics.

Put in the formerly used terminology, primary qualities were seen as purely object-sided, whereas secondary qualities as containing genetically subject-sided components as well. Historically, however, there were differences of opinion regarding what criterion would identify primary qualities, how exactly to conceive of secondary qualities, and what the reality status of secondary qualities was. What is utterly important in our context, however, is the fundamental parallel between the distinctions of primary versus secondary qualities and true motions versus apparent motions. I found only one author who has seen this parallel and their historical

[12] For general discussion of the primary–secondary distinction, see, e.g., Averill 1982; Hirst 1967; Macintosh 1976; Smith 1999; Vision 1982.

connection, namely Edwin Arthur Burtt in his influential *The Metaphysical Foundations of Modern Physical Science* of 1932:

> The secondary qualities are declared to be effects on the senses of the primary qualities which are alone real in nature. [. . .] This doctrine, too, was bolstered up by considerations derived from the Copernican astronomy. Just as the deceptive appearance of the earth, which makes us suppose it to be at rest, arises from the position and local motion of the onlooker, so these deceptive secondary qualities arise from the fact that our knowledge of objects is mediated by the senses. (Burtt 1932/1980, p. 84)

In both cases, the pertinent phenomena or qualities, only later dubbed "apparent" or "secondary," appeared prior to that to be purely object-sided, because of their phenomenological qualities and their causal efficaciousness, as could be (quasi-)experimentally demonstrated. To appreciate the causal efficacy of the later so-called secondary qualities, consider, for example, the loud bang of an explosion that may damage the eardrum; odors that influence the behavior of animals and humans; the light of a specific color that triggers a particular photochemical reaction (a Whiggish example). To appreciate the causal efficacy of the later so-called apparent motions, consider the difference between night and day, which is caused by the Sun's motion.

Consistent with their causal efficacy, in antiquity and the Middle Ages, later so-called secondary qualities and apparent motions were mostly seen as real: Their reality status was on equal footing with other unquestionably real properties.[13] Note that the same still holds for common sense (see, e.g., Chirimuuta 2015, pp. 31–37). For instance, in everyday life the material and the color of a sweater have the same reality status. In the same vein, in ordinary language we call certain people "colorblind," as if colors were something really existing outside of human beings in the real world and that these people are just incapable of grasping them.

It is interesting to see how in the Scientific Revolution, after their downgrading to secondary qualities or apparent motions, respectively, the formerly unquestionably real properties and motions changed their reality status.[14] This is because they are now seen as having lost their genuine causal powers. The general mechanism of this process is this. As soon as certain qualities or motions are seen as secondary or as only

[13] For colors, see, e.g., Chirimuuta 2015, pp. 19–22, 49–52.
[14] This holds for most authors, but not for Boyle, who insisted on the full reality status of secondary qualities; see Burtt 1932/1980, pp. 180–184.

apparent, respectively, they are no longer attributed to the respective objects themselves but are primarily located in the perceiving subject. Secondary qualities and apparent motions are the effects of the primary qualities and the true motions, respectively, on the perceiving subject. According to this view, the causal efficacy is now relocated, away from secondary qualities and apparent motions, to the underlying primary qualities and true motions. For example, it is not the loud bang of an explosion, a secondary quality, that damages the eardrum, but the underlying violent motion of the air molecules, a primary quality. Or it is not the color of the light that triggers a particular photochemical reaction, but the frequency-dependent energy of the underlying electromagnetic waves. Similarly, for motions, it is not the Sun's apparent motion that causes day and night, but the rotation of the Earth. Or it is not Foucault's pendulum's own motion alone that produces the collision with the little objects on the periphery of the swinging pendulum, but the conjunction of the pendulum's own motion with the contribution by the Earth's rotation.

The lesson of these groundbreaking changes that are essential elements of the transition from the ancient and medieval conception of science to modern science is this. It is illegitimate to infer from the *phenomenological* quality of a phenomenon as purely object-sided and as causally efficacious that it *really* is purely object-sided and is indeed itself causally efficacious. The phenomenon in question may contain genetically subject-sided components that are phenomenologically *completely* hidden. Note that this lesson is not the result of some philosophical speculation, or of skepticism,[15] but is the result of one of the greatest events in human intellectual history, the transition from medieval to modern science. It is this insight that is, together with other elements, at the bottom of modern science. Disregarding this insight means nothing less than denying the immeasurable progress that scientific thinking has made due to the scientific revolution. Disregarding this insight also means staying in a pre-Copernican scheme of thought.

For example, G. E. Moore's famous defense of realism by showing his hand and exclaiming "this is a human hand," as an example of a real object, fails because it tries to work from the phenomenological quality of his hand *alone* to its pure object-sidedness (see Moore 1925). This is like doubting

[15] I am mentioning skepticism here because often realists try to fend off arguments against realism as parts of skepticism, and as skepticism is not seen as a defensible position, the respective arguments are dismissed.

the Earth's rotation because it cannot be felt or claiming the absolute reality of the Sun's motion because it can be observed. Putting these phenomena into a greater theoretical context may change their reality status. Again, this is not skepticism; it is post-Copernican thinking.

Here is the positive result of these considerations for both science and philosophy. Whenever plausible, the possibility of phenomenologically imperceptible genetically subject-sided components of something that presents itself as purely object-sided must be considered. And this is exactly what has happened since the seventeenth century in both science and philosophy. For instance, significant parts of theoretical philosophy from the seventeenth until at least the mid-nineteenth century can be seen as controversies about the identification of genetically subject-sided components in seemingly purely object-sided phenomena: Where exactly is the dividing line between the genetically subject-sided and the purely object-sided?[16]

As I claim that this part of post-Copernican thinking is essential in the genealogy of Kuhn's metaphysics, I shall in the following very briefly sketch some historical cases where post-Copernican thinking became operative. These cases will differ with respect to their historical success, as far as we can assess it today.

1.4 Kant

Kant himself is very explicit about the line that connects his critical philosophy with the Copernican revolution. He claims that his own "Copernican turn" in philosophy is modeled upon what Copernicus did for planetary theory.[17] This means for Kant: Try to decipher phenomena that appear to be purely object-sided as having phenomenologically hidden genetically subject-sided components. For mathematics, explain the possibility of mathematical proofs by the genetical subject-sidedness of time and space. For physics, explain the existing a priori regularities in nature by their origin from the subject side. One source of inspiration for the latter is David Hume, who according to Kant's own judgement, awoke him from his "dogmatic slumber." The slumber consisted in the rationalist heritage firstly to assume causality to be purely object-sided and secondly as

[16] Arthur Schopenhauer has given a schematic description of the history of philosophy from Descartes to Kant along these lines; see Schopenhauer 1851/2014.

[17] See Kant (1781&1787/1998), ed., tr. Guyer, and Wood, pp. B XVI and especially B XXII fn. *. In the Kant literature, it was especially the German Kant scholar Friedrich Kaulbach who stressed the importance of the "Copernican thinking figure"; (see Kaulbach 1973).

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epistemically accessible to pure nonempirical thought. Instead, Hume attributed causality to the subject side and made it somehow "subjective." Kant thought that by his transcendental philosophy, he was able to agree with Hume's attribution of causality to the subject side but at the same time to restore its objective and a priori character.

Kant maintains that *all* phenomena accessible for us contain genetically subject-sided components. He also expresses this in the terminology of primary and secondary qualities: *All* physical qualities are secondary qualities, including especially space, time, and causality.[18] According to Kant, the contributions to apparently purely object-sided phenomena from the subject side are individually and historically invariable: They are the "forms" of intuition and thought. These forms are universal for human beings, and they are necessary preconditions for any experience. As our only way to get in contact with the world is through these forms, we have no access whatsoever to the primary qualities that underlie the manifest secondary qualities of real phenomena.

It is extremely important that in Kant's view, physical *reality* consists of what he calls appearances, and there is no other reality for us: Physical reality consists of causally interacting material things. *All physical reality, that is, all material things, contains genetically subject-sided elements, which do not, however, diminish in the least their status as real things*. With respect to the properties of real things, we are thus in a state like the state of the ancients with respect to colors. Colors were successfully taken as real, with causal forces, and no phenomenological investigation into colors could throw doubt on their reality. It was a disruptive change of perspective in the seventeenth century due to a new theoretical system that diminished their reality status to that of secondary qualities and transferred their causal powers to the underlying primary qualities. Kant, however, objected that these putative primary qualities are, in fact, also secondary qualities with the fundamental difference that in principle, there is no theoretical system available that allows us access to the underlying truly primary qualities. Reality is this set of causally interacting material things, and their genetically subject-sided components do not change anything in their reality.

My point in this section is not to defend Kant's position. It seems to me that today, very little of substance can indeed be defended of it. The main reason is that Kant built his position by using parts of the logical, mathematical, and scientific knowledge of his day, which he thought were

[18] Kant (1783/2004), ed., tr. Hatfield, 4:289; for discussion, see Allais 2007; Rosefeldt 2007; Allais 2015, especially pp. 125–144.

eternal. As it turned out in the nineteenth and twentieth centuries, nothing of these putative eternal truths survived unscathed; in fact, some of them were virtually abolished. But Kant illustrates how post-Copernican thinking made its way further into philosophy. We shall see in a moment that it also made its way into some of the most breathtaking innovations of twentieth-century physics.

In addition, due to Kant's immense influence, post-Copernican thinking stayed alive in the nineteenth and twentieth centuries. I shall use this term and the correlated "pre-Copernican thinking" in the following way. Pre-Copernican thinking tends to accept what appears to be object-sided, and thus real, as indeed being *purely* object-sided. It tends to trust our perception that suggests to us that things are as we perceive them.[19] By contrast, post-Copernican thinking systematically considers the possibility that what appears to be purely object-sided (and thus real) may contain genetically subject-sided components. Note that post-Copernican thinking, as I refer to it here, does not dogmatically claim that what appears to be object-sided, and thus real, necessarily contains genetically subject-sided components. It only claims that contrary to all impressions, the apparently purely object-sided, and thus real, *may* contain genetically subject-sided contributions; it is a fundamentally self-critical stance. For those people who have adopted post-Copernican thinking, pre-Copernican thinking in our days appears to be obsolete and dogmatic, "unphilosophical," or even "anti-philosophical" (see, e.g., Rowbottom 2011 against Sankey 2008). The reason is that we know since the advent of Copernicus's theory that apparently purely object-sided real phenomena may contain genetically subject-sided components.

In the nineteenth century, elements of Kant's post-Copernican thinking substantially entered, mainly through the channels of neo-Kantianism, the debates of the emerging historical humanities and social sciences, as well as the non-presentist conception of historiography. These elements stayed there and were partly even radicalized, in the last third of the twentieth century due to a particular reading of Kuhn's philosophy of science. Space limitations prevent me from discussing these developments. Instead, I will immediately jump to the physics of the twentieth century.

[19] The German word for perception, *Wahrnehmung*, nicely expresses this property of perceptions. Literally, *wahrnehmen* means something like "take the true" or "take as true." – See also Chirimuuta 2015, pp. 29–30.

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1.5 Twentieth-Century Physics

Elements of post-Copernican thinking entered into two of the most important developments of twentieth-century physics, special relativity theory and quantum mechanics. I can only sketch the basic idea.

It is one of the central assumptions of classical physics that it is an objective property of two events to be simultaneous or not. This is also taken for granted by common sense. However, Einstein realized that the simultaneity of two events is not absolute, but relative to an observer. In other words, the simultaneity of two events is not purely object-sided but contains a genetically subject-sided element, namely the state of motion of the observer. The consequence is that one and the same pair of events may be simultaneous for one observer and not simultaneous for another observer. Thus the seemingly purely object-sided simultaneity contains genetically subject-sided components, which are invisible at low relative velocities to the observers.

The role of the observer in quantum theory is even better known, which in the 1920s and 1930s led to fundamental discussions among physicists about the nature of reality. Here is one example. Newton conceived light as a stream of particles; in the nineteenth century, however, the idea prevailed that light is an electromagnetic wave. As became clear in the early twentieth century, light has both properties in irreducible ways, which appears to be a contradiction. It turned out that these irreconcilable properties of light cannot lead to a contradiction because their appearance depends on specific experimental arrangements. The experimental arrangements that make light to show its wave-like character are not compatible with the experimental arrangements that make light to show its particle-like character (see, e.g., Hoyningen-Huene 1994, pp. 241–245). Thus, the presumed fundamental objective characteristic of light, be it to consist of particles or of waves, turned out to be observer dependent. Thus, what seemed to be a purely object-sided property of light (wave or particle) turned out to contain genetically subject-sided elements, namely the specific observational conditions. Again, we see the fundamental ingredient of post-Copernican thought at work.

1.6 Kuhn's Metaphysics

Finally, I can consider Kuhn's metaphysics. The claim of this chapter is that one should understand Kuhn's very insufficiently worked out metaphysics as standing in the genealogy that I outlined in the previous sections.

Kuhn's metaphysics contains the fundamentally post-Copernican element that something that appears to be purely object-sided may also contain genetically subject-sided components. Note that putting Kuhn into the post-Copernican genealogy is, of course, not by itself an argument for its correctness. Understanding the post-Copernican genealogy only opens up a conceptual space that might otherwise be barred: that something objective and real may still contain genetically subject-sided elements that do not diminish its reality status. Familiarity with the post-Copernican genealogy may prevent immediate dismissal of philosophical positions that do look absurd from the viewpoint of common sense and of more or less naive forms of realism. However, any claim that this or that object that appears to be completely object-sided also has genetically subject-sided components must be argued for separately. In no way is post-Copernicanism a carte blanche for antirealism.

From 1979 onward, Kuhn describes his position as "also . . . Kantian but . . . with categories of the mind which could change with time as the accommodation of language and experience proceeded. A view of that sort need not, I think, make the world less real" (Kuhn 1979, pp. 418–419). This is reminiscent of Kant's description of his position as *simultaneously* transcendentally idealist and empirically realist.[20] Peter Lipton found a nice expression for Kuhn's position: It is "Kant on wheels" (Lipton 2003). Interestingly, this view had been anticipated by Einstein already in 1949 showing that it is not entirely far-fetched for a reflective physicist (see Oberheim 2016, p. 23).

Nevertheless, the parallel between Kuhn and Kant is not total with respect to the objects that contain genetically subject-sided components. Kant's forms of intuition and categories of thought are responsible for the constitution of *what physical things in general are*, that is spatiotemporal things. Thus, Kant's forms of intuition and categories of thought are constitutive of "thinghood."[21] By contrast, Kuhn's view is wider. For him, the constitution of physical things by genetically subject-sided contributions is only a special case. It only applies to the transition of classical to quantum mechanics, where the classical notion of a physical thing is abolished in favor of something like a "quantum object." In most other cases, a revolution does not affect thinghood itself, but only the existence, the qualities, and the relations of *specific things*.

[20] For discussion and quotations, see, e.g., Allais 2015, Part Three.
[21] See Heidegger and Gendlin 1985 who particularly stress this aspect.

However, in a fundamental respect Kuhn's spirit is the same as Kant's: What we *correctly* take as objective reality is nevertheless somehow shaped by genetically subject-sided components.[22] As in Kant's case, one can understand Kuhn's position by means of the secondary qualities analogy; for example, in terms of colors (see also Hoyningen-Huene and Oberheim 2009, p. 207). Suppose colors as phenomenal qualities of things are secondary qualities: They are then an amalgam of genetically object-sided and genetically subject-sided components.[23] Clearly, common sense and many sciences take colors unhesitantly for real. For instance, in paleontology the question, what the colors of dinosaurs were, appeared to be a scientifically unanswerable question for decades (all colors we see in images of dinosaurs are completely arbitrary), because these organically based colors are not preserved in the fossil record. However, in 2010 scientists found a way to reconstruct the colors of some dinosaur species, assuming the reality of those colors and their underlying molecular basis as a matter of course (Zhang et al. 2010). Since the seventeenth century, colors were identified as secondary qualities and their underlying primary qualities were investigated. Thus, the reality status of colors has been somehow undermined by the existence of underlying primary qualities (that are supposed to be purely object-sided) without, however, making the secondary qualities completely unreal. The downgrading of the reality status of secondary qualities is the effect of seeing them in the light of underlying primary qualities; without this perspective they successfully pass the reality test by being causally efficacious (in the same way as the apparent motions are).

This analysis enables us to put the metaphysics that Kuhn attempted to articulate into the tradition of post-Copernican thinking, thereby making it at least intelligible. Imagine that all observable and theoretical properties of physical things and processes are secondary qualities like colors, but as robust as the apparent motions of celestial bodies.[24] Now assume further that we have no access whatsoever to their purely object-sided components, that is, to the corresponding primary qualities. Now remember the

[22] This is what realists get notoriously wrong. For instance, Bird 2003, p. 691: "Most commentators take Kuhn's term 'world' not to mean the world of things but a world of appearances or of subjective connections (e.g., Hoyningen-Huene 1993)." I did absolutely *not* mean to oppose "appearances" to "things."

[23] This seems to be standard view in color science, but less so in color philosophy; see, e.g., Giere 2006, chapter 2; Chirimuuta 2015.

[24] Colors vary with individual observers and with observing conditions. This reduced robustness has fed the suspicion that they are not fully "objective," this is, purely object-sided; see, e.g., Chirimuuta 2015, p. 6.

treatment of apparent motions and secondary qualities in the history of Western thought before the discovery of their nature as apparent or secondary, respectively. As a matter of course, these motions and properties were taken for real both in everyday life and in science and philosophy. The main criterion for their reality very probably was their causal efficacy, a criterion that was then as persuasive as it is today. Under these circumstances, we would take all observable and theoretical properties of physical things and processes simply for real, despite their true nature as secondary qualities, which in the given scenario are inaccessible to us. Even speculations about possible underlying primary qualities would be completely unhelpful. If we have in principle no access to these primary qualities, their existence would not change our epistemic situation in the least, in comparison to the situation in which the secondary properties were, in fact, primary.

I am now suggesting that already in 1962, Kuhn had this scenario dimly in mind and that he tried to develop it during the rest of his life. Here is a central quote of SSR that is hardly intelligible by itself but is consistent with the given scenario: "In so far as [the scientists'] only recourse to [the world of their research engagement] is through what they see and do, we may want to say that after a revolution scientists are responding to a different world" (SSR-2, 111).

The "only recourse" refers, in the given scenario, to the empirical world containing only secondary qualities, without any possible recourse to the underlying primary qualities. Under these circumstances, "we may want to" speak about world change due to a revolution because there is no world accessible to us that is the same before and after the revolution.

1.7 Conclusion

In this chapter, I have tried to put the apparently strange metaphysics that Kuhn tried to develop from at least 1962 on, in a larger historical context hoping to make Kuhn's attempted metaphysics more intelligible. Some commentators tried to circumvent the difficulties of Kuhn's strange world-change talk by downgrading it from metaphysical to psychological and metaphorical. For example, noted philosopher of science Alexander Bird writes: "In summary, a change in paradigm can bring with it a range of important *psychological* changes that have cognitive (and emotional) consequences [. . .]. It is these *psychological* changes that Kuhn is referring to with the *metaphor* of 'world-change'." (Bird 2012, 869, my ital.) And "'World-change' focuses on the *psychological* consequences of a scientific

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revolution." (Bird 2012, 871, my ital.) Kuhn, however, stated: "I see no alternative to taking literally my repeated locution that the world changes with the lexicon." (Kuhn 1984, 120)

I hope to have shown that in the given genealogy, serious scientists and philosophers did not identify all changes of genetically subject-sided contributions to phenomena as necessarily psychological. On the contrary, it is the defining characteristic of the post-Copernican development that such changes may concern the very subject matter of the natural sciences, physical reality. Kuhn belongs to this tradition by using the fundamental element of post-Copernican thought and trying to make better sense of the history of science.

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