



Giere's instrumental Perspectivism

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Abstract

When Ron Giere (1999, 2006) introduced perspectivism into philosophy of science, he provided a perspectivist analysis of both scientific instruments and scientific theorizing. Today, there is a burgeoning literature that extends Giere's analysis of theorizing, with many philosophers examining the perspectivist approach to aspects of theorizing such as models, laws, explanations, and so on. However, relatively little attention has been paid to Giere's analysis of instruments. In this article, I hope to fill this gap. I argue that the perspectivist analysis of instruments ("instrumental perspectivism") should be rejected. First, I give a general account of the kind of instrumentation relevant to instrumental perspectivism, drawing on Cartwright's notion of nomological machines, which forms the basis of my criticism of Giere's argument for instrumental perspectivism. Next, I present the case against instrumental perspectivism. I argue that instrumental perspectivism is dependent on theoretical perspectivism in a way that robs it of philosophical significance, and that it introduces new puzzles while adding little to our understanding of instruments.

Keywords Perspectivism · Realism · Instruments · Nomological machines · Models

1 Introduction

Perspectivism was introduced to contemporary philosophy of science by Ron Giere (1999, 2006), and was conceived as a kind of limited realism, a *via media* between what Giere calls "objectivist realism" and various forms of antirealism such as social constructionism. While the objectivist realist holds that science aims

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to provide us with a true and unique account of the way the world is, Giere argues that the methods of science provide access to the world only from particular perspectives, in a way that is analogous to how colour perception arises from the interaction between the world and our visual perspective. Although colour perception allows us to track genuine regularities in the environment, and our colour-judgements can be true or false, such judgements can be evaluated only within a given visual perspective. Similarly, scientific knowledge is dependent on our instrumental and theoretical perspectives. While some perspectives may be better than others in particular respects depending on our purposes, none of them can provide a complete or fully precise picture of any system, and none of them amount to the “view from nowhere” that it is sometimes thought that science achieves. Summarizing how his view differs from objectivist realism, Giere writes:

For a perspectival realist, the strongest claims a scientist can make are of a conditional, qualified form: “According to this highly confirmed theory (or reliable instrument), the world seems to be roughly such-and-such.” There is no way legitimately to take the further objectivist step and declare unconditionally: “This theory (or instrument) provides us with a complete and literally correct picture of the world itself.” (Giere 2006: 5–6)

Since Giere’s book was published, much has been written on whether perspectivism provides a plausible analysis of models, laws, explanations, and various other activities involved in theorizing (I will call this kind of perspectivism “theoretical perspectivism”). However, there has been little work on Giere’s perspectival analysis of instruments (“instrumental perspectivism”). I suspect that part of the reason for the relative lack of interest in instrumental perspectivism is that Giere himself presents it as a less controversial thesis as part of his book that ultimately aims to defend theoretical perspectivism. As we shall see later, it is not clear that instrumental perspectivism can be used in this way. In any case, instruments are interesting in their own right, and it is worth exploring the connections between instrumental perspectivism and theoretical perspectivism. In this article, I hope to make some progress towards filling this gap in the perspectivist literature.

An immediate problem with examining perspectivism in general is that it is not entirely clear what perspectivism is. A variety of different approaches to perspectivism have been developed in the literature (see for example the essays in Massimi and McCoy 2019). How does perspectivism relate to realism, pluralism, and pragmatism? What is the perspectivist account of truth? Is perspectivism committed to epistemic relativism? There is still no consensus on questions such as these about the basic commitments of perspectivism and what problems it faces. This problem is mitigated somewhat in this article in virtue of the fact that the kind of instrumental perspectivism defended by Giere has not received much discussion outside of Giere’s own work. Here, then, “instrumental perspectivism” refers specifically to Giere’s view of instruments. But it is worth being clear from the outset that there may be other possible approaches to instruments that would

appropriately be called “perspectivist”, but to which the arguments presented here are not relevant.¹

Before examining the details of instrumental perspectivism, it is worth noting the overall structure of Giere’s argument as it appears in his book. As Giere initially presents it, the case for instrumental perspectivism develops in three steps (for a summary, see Giere 2006: 14). In step one, he argues for a perspectival account of colour vision. In step two, he takes it that perception in general is perspectival: “I will assume that the considerations suggesting that colour vision is perspectival can be extended to human perception more generally” (2006: 14). Finally, he argues that the features that make colour vision perspectival are shared with scientific instruments: “observation using instruments is perspectival in roughly the same ways that normal human colour vision is perspectival” (2006: 41). Given this structure, it would seem that the natural path for an article on instrumental perspectivism would be to analyse the relation between perception and instrumentation. I think, however, that this topic should be avoided here. First, note that Giere’s first step is controversial among philosophers of colour. There are a variety of other accounts of colour vision, and no consensus that a perspectival account is right (for a realist account, see Byrne and Hilbert 2003, for an antirealist account, see Hardin 1988). The second step is also controversial, and surely one that Giere is not entitled to make without argument. It is not at all obvious that colour perception is relevantly similar to other forms of perception; much of the debate over primary and secondary qualities revolves around just this question. However, in my view none of this is really a problem for Giere. In presenting instrumental perspectivism as an extension of perceptual perspectivism, Giere is committing himself to much more than he needs to, because the third step of his argument – where he details specific properties of instruments that render them perspectival – would, if correct, be sufficient in itself to establish instrumental perspectivism, regardless of how instruments relate to perception. I suspect that the reason why Giere appeals to perception is that he wants to build from a less controversial claim, perceptual perspectivism, to the more controversial one of instrumental perspectivism; but my own impression is that given the debates about the nature of perception, perceptual perspectivism is no less controversial than instrumental perspectivism.

I take Giere’s discussion of perception to provide a loose analogy to instruments, rather than as being a crucial part of the case for instrumental perspectivism. So in this article, we will put the question of the nature of perception to one side, and examine the properties of instruments directly. In particular, Giere cites two properties as constituting the perspectival nature of instrumentation: *partiality* and *opacity*. The rest of this

¹ One notable example is van Fraassen (2008), whose work an anonymous reviewer suggested would be relevant. While van Fraassen’s account of instruments is sometimes classed as perspectivist, I do not think he endorses a form of perspectivism anything like Giere’s, and so I take his work to be outside the scope of this paper. In particular, as a perspectival realist, Giere treats instruments as revealing otherwise unobservable properties in the world, but in ways that are always *partial* and *opaque* – these terms will be explained in more detail shortly. Van Fraassen simply denies that instruments need to be thought of as revealing anything in the world: all instruments can be viewed as “engines of creation”, machines for generating new observable phenomena, as opposed to “windows on the unobservable world”, the standard realist view that instruments extend our observational capacities. It is interesting to note that perspectivism in Giere’s sense does not seem to fit either of van Fraassen’s metaphors; the instrumental perspectivist attempts to find a *via media* between the “engines of creation” and “windows on the unobservable” views.

paper is divided into four sections. In section 2, present a general account of the kind of instrumentation relevant to instrumental perspectivism, drawing on Cartwright's (1999: 50) notion of nomological machines. In section 3, I examine Giere's case for instrumental perspectivism, focusing on the properties of partiality and opacity. I find that Giere's arguments do not justify the perspectivist account of instruments: partiality is trivial, while opacity is not well-defined in that it conflates two concepts, transformation and distortion. I conclude that the instrumental perspectivist needs to defend the idea that instruments distort, a topic that is explored in section 4. This section and the next develops the case against instrumental perspectivism, as we will see that instrumental perspectivism is dependent on theoretical perspectivism in a way that robs it of philosophical significance, and that the notion of instrumental perspectives introduces new puzzles while adding little to our understanding of instruments.²

2 Instruments as causal processes

There are many types of instruments used in the sciences, and it may not be reasonable to expect a philosophical analysis of instruments to apply to all of them. In this article, I will follow Giere and focus specifically on "detection instruments", instruments whose output is taken to represent systems in the world, and that are used to detect otherwise unobservable phenomena or to correct our judgements about observable phenomena (see Harré 2003, 2010 for a taxonomy of scientific instruments in general). Henceforth, the term "instruments" will be used to refer specifically to detection instruments.

When thinking about scientific instruments it is useful to consider what I am calling the *instrumental model*.³ The instrumental model is a model of the production of the instrument's output. A key point here is that instruments are special types of causal processes, and this causal process is described by the instrumental model. Instruments are nomological machines in Cartwright's sense; Cartwright defines a nomological machine as "a fixed (enough) arrangement of components, or factors, with stable (enough) capacities that in the right sort of stable (enough) environment will, with repeated operation, give rise to the kind of regular behaviour that we represent in our scientific laws" (Cartwright 1999: 50). The instrumental model tells us how the processes going on in the world plus the functioning of the instrument produce a particular output. With the instrumental model we can draw conclusions about the

² An anonymous reviewer raised an objection to the structure of this paper: namely, that since Giere defends not just instrumental perspectivism but a general scientific perspectivism, according to which all knowledge produced by various different scientific tools and methods, including instruments, is perspectival, then it is simply not a problem for him if instrumental perspectivism is dependent on theoretical perspectivism. I disagree with this interpretation of Giere, for one thing because, as already indicated, Giere himself treats instrumental perspectivism as less controversial than theoretical perspectivism. I take Giere's "scientific perspectivism" to consist in a conjunction of separate claims (instrumental perspectivism and theoretical perspectivism). However, I acknowledge that the reviewer's interpretation is a reasonable one. I therefore point out that we could instead frame the argument of section 4 not so much as an objection to instrumental perspectivism, but as an attempt to provide clarity on its relation to theoretical perspectivism. It is an interesting question whether Giere's instrumental perspectivism is plausible in itself, apart from his perspectival account of models, in which case my argument for the dependence of the former on the latter should still be worthwhile.

³ My account of instruments is very much in line with that of Rothbart (2007), though he talks of "design plans" rather than "instrumental models".

world from the instrument's output. The output of the instrument is modelled as the end of a causal chain; and this allows us to use the output to infer something about an earlier stage in the causal chain or another object in the causal chain.

Let's take Giere's example of gamma ray observations of the Milky Way (Giere 2006: 45–48). Different types of telescopes are sensitive to different wavelengths of electromagnetic radiation.

The Imaging Compton Telescope, or COMPTEL, uses Compton scattering to detect gamma rays. Compton scattering occurs when a photon collides with a charged particle such as an electron, causing the photon to be scattered and the electron to recoil. The photon loses energy to the electron, and the angle of the electron's recoil is determined by the amount of energy it receives.

Very briefly, the instrument works as follows. It consists of two detectors, each surrounded by photomultiplier tubes. Each tube is sensitive to gamma rays in the range of 1 to 30 MeV. The incoming gamma ray is Compton scattered in the first detector, losing energy; the recoiling electron produces a scintillation measured by the photomultiplier tubes. The gamma ray is then Compton scattered again in the second detector, again producing a scintillation measured by photomultiplier tubes. From the intensities of the two scintillations we can infer the energy of the original gamma ray. The organization of the photomultiplier tubes also allows the direction of the gamma ray to be determined. The entire instrument is surrounded by a scintillator shield that detects any stray charged particles whose interaction with the detector can be discounted.

Scientists use the data generated by COMPTEL to construct images of the Milky Way. We understand these images, and can use them to draw conclusions about the Milky Way, only given the instrumental model and various background theories and assumptions – that is, we use these images to draw conclusions about the Milky Way only because we understand the production of gamma rays in the Milky Way, and we understand the way that gamma rays interact with other particles, etc. This is what allows us to conclude that a bright spot on an image produced by COMPTEL shows us an especially intense source of gamma radiation. The instrumental model is itself drawn, of course, from various background theories and models: the instrumental model of COMPTEL includes Compton scattering and scintillation, processes that are described and explained by physical theory.

The instrumental model is incomplete, or imprecise. In explaining how COMPTEL functions, we do not say exactly what its input and output will be. Instead we make only conditional claims: if its input is X, its output will be Y. The instrument's output allows us to precisify the instrumental model: by specifying the output of the instrument, it thereby specifies or at least narrows down the possible input. When we embed a particular output into the instrumental model, it makes one part of the instrumental model precise, and so also makes precise other parts of it. Of course, it cannot achieve a complete precisification. Measurement of the direction of a gamma ray may be affected by various factors such as atmospheric conditions. Hence from the output, we can infer the location of a source of gamma radiation only within a particular margin of error. The instrumental model itself often tells us the margins of error: thus the influence of atmospheric conditions are included in instrumental models of telescopes.

At this point a potential objection arises. The instrumental model is important because it allows us to interpret the terminus of a causal chain comprising a

nomological machine. But we can of course perform further manipulations on an instrument's output, and so create further outputs from it. It might seem that in some of these cases we can dispense with the instrumental model, since humans need not interpret the output of an instrument. Consider the many cases where scientists use computers to analyse the output of instruments and they never even see the raw data that is fed into the computer: Humphreys (2013: 65) discusses how in computerized tomography, we use computers to manipulate sinograms to draw out information that would not otherwise be accessible to a human. One of the consequences of the emergence of big data (Lyon 2014) is that it's often simply impossible for scientists to interact with all the raw data from instruments.

How does the view outlined here account for this? I would say that in cases where a computer manipulates the data before it is interpreted by scientists, this can be viewed as simply an extended instrument, understood in terms of a new, extended instrumental model. Note that computer manipulation of data is only useful when the manipulations are well-defined and well-ordered so that we can rely on it to produce a particular type of output. To take a simple example: Suppose that instrument X produces output a and instrument Y produces output b . Here we have two outputs. It may then be useful to combine a and b to generate new data c . For example, we might combine an image of the Milky Way produced by COMPTEL with an image produced by an ultraviolet telescope – say, if our best theory of star formation entailed that stellar nurseries emitted strong radiation in specific gamma ray and ultraviolet wavelengths. Obviously, the combination of a and b into c could be done by a computer; in principle scientists need not interact with a and b at all. But to have any understanding of c , scientists must still appeal to the instrumental models of X and Y. If we have set up a system where a computer regularly generates output of type c from output of type a and type b , so that scientists can ignore output of type a and type b , then $X + Y + \text{computer}$ can be thought of as a new instrument, and the instrumental model is a model of the production of output of type c . Computer manipulation of data is of course often much more sophisticated than simply combining images, but I think the same point applies. So, I don't think that computation challenges what I have said about instruments.

To summarize my view of instruments: Instruments are nomological machines, well-ordered causal processes, and we can draw conclusions about the world from our use of instruments by appealing to an instrumental model that describes the causal connections between systems in the world and the output of the instrument. I hope that what I have said so far is not too controversial. I don't think that Giere would disagree with any of this. What then is the case for instrumental perspectivism, and what does this view add to our understanding of instruments?

3 Partiality and opacity

In this section we will examine Giere's argument for instrumental perspectivism, which proceeds by attempting to show that particular properties of instruments support a perspectival analysis. Giere's basic intuition is that instruments do not simply reveal how the world is; rather, they reveal how the world is *from a particular point of view*. So, as noted in the introduction, Giere intends to defend a kind of qualified realism – a

perspectival realism. More precisely, according to Giere, instruments are perspectival in two ways:

First, like the human visual system, instruments are sensitive only to a particular kind of input. They are, so to speak, blind to everything else. Second, no instrument is perfectly transparent. That is, the output is a function of both the input and the internal constitution of the instrument. (Giere 2006: 14)

I will call the first property *partiality*: instruments are partial in that they respond to only a certain type of input. I will call the second property *opacity*, as Giere describes it as the instrument failing to be “perfectly transparent”: instruments are opaque in that the output of any instrument depends on the input plus the instrument’s internal processing. Before discussing these properties in detail, the first important point to note about Giere’s view here is that it is only concerns the properties and operation of scientific instruments. I emphasize this because perspectivism is sometimes construed as the claim that we have knowledge only of perspectival facts, or perhaps that all facts are perspectival; for example, Chakravartty (2010: 407–408) interprets Giere’s discussion of instruments as an argument for the claim that the facts detected by instruments are perspectival. While there is no doubt that some of Giere’s comments about perspectivism in general can be interpreted along these lines, it is clear that neither partiality nor opacity in themselves entail anything about the objects observed. Partiality and opacity are properties of scientific instruments. So I am reluctant to attribute contentious metaphysical concepts like “perspectival facts” to the instrumental perspectivist. Other forms of perspectivism may involve a commitment to perspectival facts, but instrumental perspectivism need not.

Giere discusses several different instruments, but a single example will suffice to illustrate the main philosophical points, so we will take COMPTEL, already discussed earlier. It’s not difficult to see how COMPTEL exhibits both partiality and opacity. COMPTEL is partial because it is sensitive only to a particular range of electromagnetic radiation. It cannot measure visible light or neutrino flux or sound. It is opaque because its output depends on processes internal to the instrument, such as the structure of the photomultiplier tubes. Images constructed from the data provided by other types of detector would provide very different views of the Milky Way. What COMPTEL produces is not simply an image of the Milky Way, but an image of the Milky Way from a particular instrumental perspective; as Giere puts it: “Observation does not simply reveal the intensity and distribution of gamma rays coming from the centre of the Milky Way, it reveals the intensity and distribution of gamma rays *as indicated by COMPTEL or OSSE or...*” (2006: 48; emphasis in original). Later Giere says that we “cannot detach the description of the image from the perspective from which it was produced” (2006: 56). In analysing the output of any detector, we must consider the internal structure and processing of the detector itself.

There is no question that instruments are sensitive to a particular type of input, and that the output is dependent on the internal processing of the instrument. In the rest of this section we will consider what we should make of this fact. Do these properties challenge a realist account of instruments, or require the realist to qualify her realism in any way?

Partiality can be dealt with swiftly. Clearly COMPTEL is partial, as it is sensitive only to electromagnetic radiation within a certain energy range and can only detect gamma rays that actually reach the Earth; regions of denser gas and dust throughout the galaxy will obscure many parts the sky. Furthermore, analysis of the data may eliminate some of the detection events. Partiality is not a controversial thesis, and it's hard to see how it could support any particular philosophical analysis of instrumentation. You don't need to be an instrumental perspectivist to see that instruments are responsive only to certain types of input; both realists and antirealists will also accept this. One way to see the problem for the instrumental perspectivist position here is to ask: what is the alternative? What would it mean to reject partiality? If an instrument were not partial, then it would be sensitive to everything. Even if such a thing is logically coherent, there would obviously be no way to use it. Instruments are useful precisely because they are used to track only specific properties that we are interested in. Since everybody accepts partiality, instrumental perspectivism is trivial if it rests on this claim.

Let's turn to opacity. This is the claim that the output of an instrument is dependent on the input plus the internal processing of the instrument. Now initially it may seem that this, like partiality, is a trivial claim, which poses no challenge to the traditional realist. The images produced by COMPTEL depend on its internal processing; obviously, without any internal processing, it wouldn't produce any images at all. A different gamma-ray telescope, sensitive to exactly the same wavelengths, may well produce different images. Imagine that aliens who see only in ultraviolet light develop their own COMPTEL telescope; the images this instrument produces would look different, since it had been constructed for the ultraviolet-sensitive eyes of the aliens.

So it may be thought that opacity is again trivial, in which case the philosophical significance of Giere's instrumental perspectivism is lost. But the perspectivist draws a controversial moral from the fact that the output of an instrument is dependent on its internal processing. One of the central ideas of instrumental perspectivism is that perspectives contribute to the content of an instrument's output, and therefore an instrument only ever shows the world *as it appears from that instrument's perspective*, not the world as it really is. This is one way in which perspectivism challenges standard realism: we never have access to the world, without qualifications; only the world from a particular perspective.

We can get a clearer idea of what opacity involves if we consider what it would take for an instrument *not* to exhibit opacity. Look at a tree, and then look at a tree through a window. The window is literally transparent. If we were to interpret the window as an instrument, we might say that the "output" of the window (what will be detected on the other side of the window) depends only on the input, since the "internal processing" of the window makes no difference to how the scene outside appears to the eye. Of course, this is not quite true. There will always be some detectable differences between looking at a tree and looking at a tree through a window. But the information reaching your eyes in the latter situation may increasingly approximate the information reaching your eyes in the former. The key point is that in most contexts, a clear window does not transform the information in any significant way. The window-instrument exhibits *partiality*, since it allows only certain types of input through – electromagnetic radiation in the visible spectrum – but it is not *opaque*; it does not alter the information. Given the input, we could predict the nature of the "output" without considering the window at

all. This is not the case for a gamma-ray telescope or an fMRI scanner. In that sense the window-instrument shows the world “as it really is”, whereas the output of the gamma-ray telescope and the fMRI machine is “conditioned” by these instruments.

However, there are at least two problems with the paragraph above. First, it does not seem right to say that the window shows the world as it really is. Speaking more carefully, the situation is that what we see when we look through the window is relevantly similar to what we see when the window is not there. The transparency of the window lies in the fact that it makes no difference to what is seen. This points to the second problem, which is that it is simply bizarre to interpret a window as any kind of instrument. Instruments are used to make our discriminations more reliable, or to detect properties that would otherwise be undetectable. But this requires that information otherwise hidden to us be transformed into something that we can perceive in some way. Under normal circumstances a window doesn’t detect anything. Light simply passes through it, and as a result we see through it to whatever is on the other side. The window is transparent in that its “output” does not depend on its internal processing, and for precisely this reason, it is totally useless as an instrument. The moral: in order for something to be an instrument, we must be able to use it to detect properties in the world, and in order to do this, it must alter the information about those properties. But now it seems that detection uncontroversially *requires* opacity! After all, no realist would want to say that instruments are literally like windows. All parties to the debate accept that instruments involve transformation of information.

Consider again the example of COMPTON. We can’t detect gamma rays. So the input must be altered by the instrument in order for it to be of any use to us. By transforming the input from, say, a distant galaxy the instrument makes certain properties of that galaxy salient to us, properties that would be invisible to us were it not for the instrument. Now should we say that the instrument is not revealing the world as it really is? The only way I can make sense of such a claim would be that since the instrument transforms the input, it thereby *distorts* the input. In this sense the instrument contributes to the output.

In my view there is a serious confusion here. I think that part of the appeal of instrumental perspectivism rests on conflating *what* is detected with the *means by which* things are detected. The point is perhaps best seen by returning to the comparison with visual perception. We might say, speaking loosely, that we perceive light – but of course this is not true, at least not in normal circumstances: rather, we should say that we perceive objects, and light is the means by which we perceive objects. Similarly, the internal workings of the visual system are part of the means by which we perceive objects. Processes involving light, the lens of the eye, the retina, the optic nerve, the lateral geniculate body, etc., contribute to the content of visual representations insofar as we wouldn’t have those representations without those processes occurring. In general, there is not a detection of X without some process occurring that constitutes the detection, i.e. without there being a vehicle for the detection.

With this in mind, what exactly is it that is being distorted by the instrument? The gamma-ray telescope allows us to detect properties from a distant galaxy by transforming a certain type of information from that galaxy. It makes no sense to view this transformation as any kind of distortion because the transforming processes are the means by which the properties of the galaxy are detected! Obviously these properties are not themselves distorted. We can’t change the properties of a distant galaxy. There

are some situations where detecting the properties of a system changes the system, but this isn't one them, and in any case such situations are irrelevant to the instrumental perspectivist's point. To sum up: Giere's concept of opacity seems to combine both notions of transformation and distortion. Detection requires transformation, and transformation is not distortion (not in itself at least). What then does it mean to say that an instrument is opaque? If it means that the instrument transforms, then this is true but, like partiality, trivial. In order for an instrument to detect otherwise unobservable properties, there must be some processes occurring in the instrument that transform the information. If opacity means that the instrument distorts, this is controversial but not adequately supported by Giere's argument.

4 Do instruments distort?

According to Giere, instrumental perspectivism consists in the fact that all instruments are both partial and opaque. If the argument of the previous section is correct, then what is philosophically controversial in instrumental perspectivism is the idea that instruments *distort* information. This section therefore takes up the question, in what sense could an instrument distort information? Given the argument of the previous two sections, it might be argued that there is something misleading in describing the output of any instrument as either distorted or veridical. Instruments are well-ordered causal processes that transform information. On the basis of the output of the instrument we draw conclusions about the world that may or may not be correct, depending on whether we are applying the right instrumental model. It is only when we make inferences from the output that the question of distortion arises. However, I think that this conclusion is too quick, and that the instrumental perspectivist can make sense of the idea that instruments distort. The key is that an object counts as an instrument only if it is used by people in the right kind of way: in particular, people must apply an instrumental model to it. Without the instrumental model, we cannot specify what the "input" or "output" of the instrument are; we don't really have any data at all on the basis of which we might make any claims about the world. Put simply: there is no instrument without an instrumental model.

It is true of course that instruments sometimes create surprising phenomena that are not covered by any theory or model: Roentgen's fortuitous discovery of X-rays is a classic example here. But note that such surprising discoveries are surprising only against a background understanding of previously accepted theory. Initially, Roentgen was simply faced with a strange phenomenon that he couldn't explain: a faint green glow on a barium platinocyanide screen, produced while operating a cathode ray tube. Surely this didn't count as a discovery of X-rays, or as a perspective on X-rays, or anything like that. It took seven weeks of work before Roentgen had any idea what he was looking at. All Roentgen had before some theoretical understanding had been achieved was a literal "engine of creation" in van Fraassen's (2008) sense: set this equipment up in the right way, switch it on, and you get a faint green glow. Perhaps we could still call this an "instrument" of some sort, but clearly we have an X-ray *detection instrument* only when we can use the screen to take measurements of X-rays. The issue is that without an instrumental model, we can't link up the phenomena produced by a piece of equipment to other processes in the world. How do we know that we have an

image of the Milky Way – or even just an image of the Milky Way *from the perspective of COMPTEL*? Only as a result of some model linking processes in the Milky Way to the functioning of the COMPTEL instrument. In general, something is a detection instrument only when it is used to take measurements of systems, and that requires an instrumental model.

In the literature on measurement, it is standard to distinguish four different types of measurement scale: nominal, ordinal, interval, and ratio (Stevens 1946; Tal 2013: 1164). In a nominal scale, objects are sorted into sets without any specific order, as when we sort people into male and female, or we sort people into different nationalities. An ordinal scale sorts the measurands into a particular rank order: the Mohs scale of hardness ranks minerals into ten categories based on whether one can scratch another. This scale is qualitative and no meaningful arithmetical operations can be performed on it, since there is no way to combine degrees of hardness. An interval scale has equal intervals, and so allows arithmetical operations on the intervals of the scale but not on specific values of the scale. Consider the Celsius temperature scale. We cannot say that 100 °C is twice as hot as 50 °C, because the zero point is arbitrary. However, the difference between 100 °C and 50 °C is the same as the difference between 50 °C and 0 °C. Finally, a ratio scale also has equal intervals but the zero point is not arbitrary. 100 kg is twice 50 kg, and 0 kg is no mass.

We cannot make sense of a measurement of a particular quantity unless it is placed within a measurement scale. If I say that topaz has a hardness of 8 on the Mohs scale, this information is useless unless you know what kind of scale the Mohs scale is, and you know where various other items are placed on the scale. It almost goes without saying that no instrument can in itself specify a measurement scale. The type of scale used must reflect the relations between the objects being measured, and this imposes limits on how we might analyse data from an instrument. As Hand (2004: 73) says, “when regarding the numbers as measurements of some underlying property, only those operations may be performed which correspond to some empirical operation between the objects measured.” The instrumental model is what specifies this correspondence.

Furthermore, even with the measurement scale given, the instrument cannot itself give the value of the measurand. In order to make a measurement, we must fix the appropriate degree of precision. Collins (2010) gives the example of measuring height. Suppose I want to convert my height from inches to centimetres. If my height is 69 in., and if I know that there are 2.54 cm to an inch, then I can calculate that my height is 175.26 cm. But Collins points out that convention does not allow me to say: “my height is 175.26 centimetres.” This is not an acceptable measurement report; we do not measure heights to the one hundredth of a millimetre, because we know that height varies by several hundredths of a millimetre even between a person’s breaths. Instead I might say that my height is 175 cm, or 175.3 cm, or 175.5 cm, depending on context. How do we decide what counts as an appropriate degree of precision? Among other things, we have to consider the properties of the measurand, and also the margin of error of the instrument. The margin of error is given by the instrumental model.

Instruments are used to take measurements. Taking a measurement requires specifying a value within a particular scale, and to a particular degree of precision. The output of an instrument cannot in itself reveal the properties of any object. To draw a conclusion about the object, we must locate the instrument’s output in a logical space

provided by the instrumental model and background theory (cf. Van Fraassen 2008: 164).

Am I overstating the dependence of instruments on theory? Many writers have argued that instruments are in some important sense independent of theory: Hacking (1983) urges that some experiments have “a life of their own”, as it were, and can be conducted without guidance from theory. In particular, arguably we can know that an instrument is reliable without appealing to any sophisticated theory. But the key point here is *sophisticated theory*. Instrumental models need not be theoretically sophisticated, and much literature has examined the ways in which models are constructed relatively independently of theory (e.g. Morgan and Morrison 1999). You don’t need to know the precise details about the nature of light in order to understand the instrumental model of the optical microscope: this model – which details the path of light through various lenses to the eye of the microscope user, the creation of a real image, a virtual image, etc. – has been in use since the earliest days of microscopes, surviving through corpuscular theories, wave theories, and the photon theory. Even Hacking accepts that in order to make any judgements about unobservable entities, we need to know various “home truths” about them, certain basic generalizations about important causal properties (Hacking 1983: 265). Such home truths are enough for the instrumental models of instruments. I take it that those who assert the independence of instruments from theory mean by the word “theory” something more like a complex, formalized system, intended to apply to a wide range of phenomena, and perhaps partially built on universal laws.

There can be no instrument without an instrumental model. It is not quite correct that we have an instrument, with a particular type of output, and then we draw inferences about the world by applying the instrumental model to that output. The instrument and the instrumental model are more closely intertwined than that. To identify some event as the output of a detection instrument is already to apply an instrumental model to it. So there *is* a sense in which instruments can be said to distort, because the instrumental model may be mistaken in various ways. Recall the point made by Hand that the permitted operations on numbers of a measurement scale must correspond to some empirical operation between the measurands. We may be mistaken about what these empirical operations are. On this point then, the instrumental perspectivist is vindicated. Furthermore, there is some *prima facie* plausibility in the idea that even our best instrumental models are subject to distortion, because as Levins (1966) argues, all models face a trade-off between accuracy, precision, and generality, and so there can be no perfect and complete model of any system. All models will feature limitations and idealizations. Whether the realist can accommodate this fact is beyond the scope of this paper (see for example Shaffer 2012 for a defence of realism on this point); but it does provide some initial support to a perspectival account of all instrumental models.

However, this is a Pyrrhic victory for the instrumental perspectivist. The key thing to note about this defence of instrumental perspectivism is that it renders instrumental perspectivism dependent on theoretical perspectivism. In particular, we can defend instrumental perspectivism only by defending a perspectival account of the instrumental models. The distortion in the instrument is due to inaccuracies in the instrumental model; if a realist account of the instrumental model is correct, then the instrument simply tracks properties in the world and it would make no sense to treat its output as distorted. So on a realist interpretation of instrumental models, there can be no case for

a perspectival analysis of instruments. One way to see this point is to note that even if we treat instruments as perspectival, a correct model of the internal processing of an instrument will allow us to “step outside” the instrument’s perspective. This point is nicely illustrated by how we use our theoretical understanding of how visual perspectives operate to escape the limitations of our own specific visual perspective. As Chakravartty writes:

From the perspective I had of Peter over lunch in the Senior Common Room, he seemed a fairly tall man, but as I saw him in the distance some time after parting, he seemed rather small. This sort of perspectivism is uncontroversial because there are non-perspectival facts of the matter about the dimensions of Peter in our inertial reference frame that, in conjunction with facts about optics and my visual sensory apparatus, underwrite the differences in the appearance of his size. There is a height that he is, and then many ways he may appear to be from different perspectives. (Chakravartty 2010: 406)

Recall Giere’s example of COMPTEL. Part of the intuitive appeal of instrumental perspectivism lies in the fact that when we use COMPTEL to create an image of an object, such as an image of the Milky Way, the object will appear very different to how it appears to the naked eye. So there is surely some sense of the word “perspective” in which it is true to say that this is an image of the Milky Way from the perspective of COMPTEL. But this difference simply results from the fact that COMPTEL is designed to reveal different properties to what is detected by the naked eye. Then what allows us to claim that we have an image of the Milky Way from the perspective of COMPTEL is some model of the functioning of COMPTEL and its relation to processes going on in the Milky Way. If this model is correct, then COMPTEL does not distort. In the same way, a realist would insist that the human visual system does not distort the size of Peter when the amount of the visual field that Peter occupies changes with changing distances. Indeed, it is precisely this feature of the visual system that allows us to estimate Peter’s true size! Put simply then, distortion resides in the instrumental model, so instrumental perspectivism requires a perspectival account of the instrumental models.

One might object at this point that I have overlooked other ways in which instruments can be said to distort.⁴ In particular, consider phenomena such as spherical aberration, where the light rays from a lens do not all converge on one focal point. In this case, even if we had a completely correct instrumental model, and so could draw the right inferences about the input to the instrument, intuitively there is still some sense in which the optics distort. Isn’t spherical aberration a source of distortion, even when we accurately model the spherical aberration? After all, it’s natural to speak of using combinations of lenses to “correct” spherical aberration. One way to put this objection is that not all kinds of transforming processes are equal: it’s not enough simply to have a model which correctly describes how an instrument transforms the input; we also prefer particular kinds of transformation processes over others.

⁴ I thank an anonymous reviewer for raising this objection.

My response to this is that while I agree that it is intuitive to describe spherical aberration as a form of “distortion”, I am not sure that we are using the term in the sense that is relevant to the instrumental perspectivist. The “distortion” involved in spherical aberration is a practical matter. What exactly is the problem with spherical aberration? It is that spherical aberration reduces resolution and clarity, so optical instruments that are subject to spherical aberration are more difficult to work with, and worse, information about the input will be lost. Suppose we are observing a specimen using a microscope with severe spherical aberration; suppose also that our instrumental model of the microscope models the aberration. Since the image of the specimen is blurred, we won’t be able to acquire as much information about the structure of the specimen as we would with a corrected microscope. What’s more, the information we are able to acquire will be harder to get, simply because it is harder to work with a blurred image of a specimen than a sharp one. There are very good pragmatic reasons for preferring particular types of instruments, and particular types of instrumental models. However, I cannot see how this poses any challenge to a traditional realist. All parties to this debate accept that instruments produce a variety of artefacts; that we need to keep track of the particular ways in which instruments transform information; and that sometimes we need to “correct” our instruments, i.e. alter the transforming processes so as to be more practically useful. Everybody who has attempted to use an instrument like a microscope will be painfully aware of these points, no matter what their philosophical commitments. If instrumental perspectivism is understood as involving the kind of “distortion” we find in spherical aberration, instrumental perspectivism is of little significance.

The dependence of instrumental perspectivism on theoretical perspectivism may not in itself seem to be a problem; after all, I have said nothing to show that a perspectival account of the instrumental models is implausible. So far, my aim has simply been to make clear the relation between instrumental perspectivism and theoretical perspectivism. The former is dependent on latter – but perhaps the latter is true. So why did I describe this dependence as a Pyrrhic victory for the instrumental perspectivist? Because it has two negative consequences. First, it damages the overall structure of Giere’s argument. As I noted in the introduction, in developing the case for theoretical perspectivism, Giere presents instrumental perspectivism as the less controversial thesis: he first argues for perspectivism about colour vision, then extends this argument to instrumental perspectivism, and finally, and “more controversial still”, to theoretical perspectivism (Giere 2006: 14); see also an earlier work where Giere argues for perspectivism in observation and then claims that “the extension of perspectivalism to the level of scientific theory is more problematic but, I think, equally convincing” (Giere 1999: 81). If I am right, Giere has things backwards. Instrumental perspectivism rests on theoretical perspectivism.

Second, more importantly, the philosophical significance of instrumental perspectivism seems to be lost. Presumably, one would attempt to defend instrumental perspectivism specifically only if there is a reason for thinking of instruments as perspectival that does not apply to the many other entities and processes described by scientific models. So should we view instruments as being perspectival in some way that the host of other targets of scientific models are not? I think this would be a mistake. An instrument is a nomological machine understood in terms of the instrumental model. The instrumental model tells us how the instrument operates and how it connects to the world. If such models are perspectival, then the claims we make about

the world on the basis of our instruments will presumably be perspectival also. Similarly, if models of the Sun are perspectival, then the claims we make about the world on the basis of observed solar phenomena will presumably be perspectival also. The perspectivist doesn't take the Sun to be a perspective, and she shouldn't take instruments to be perspectives either. Attempting to apply the notion of perspective to the instrument itself adds little to our understanding of instruments and in fact creates puzzles, as I shall now outline.

5 The indeterminacy of instrumental perspectives

In this section I will raise two puzzles for the concept of instrumental perspectives. First, it is very difficult to specify what the perspective of a given instrument actually is. Consider the title of one of the subsections of Giere's paper on instrumental perspectivism: "The Milky Way in Gamma Ray Perspectives" (Giere 2006: 45). Why suppose that we have a gamma-ray perspective on the Milky Way, rather than a perspective on gamma rays from the Milky Way? What's the difference? The problem arises from the fact that the behaviour of stars in the Milky Way, and the gamma rays produced by the stars, and the processing of the instrument that detects gamma rays, are all causal mechanisms involved in the production of the instrument's output. The "perspective" seems to include whichever part of the causal chain we are taking for granted when investigating some earlier part of the causal chain. Another way to make this point is to ask what a given perspective is a perspective on, i.e. what the target of the perspective is? Take an image created by COMPTEL, such as an image constructed from data of gamma rays at 1.8 MeV. Perhaps it represents the Milky Way galaxy. Perhaps it represents the decay of aluminium-26, since gamma rays of 1.8 MeV are produced by the decay of this element. Perhaps it represents sites of nucleosynthesis in the cores of massive stars, as this is where aluminium-26 is primarily produced and its concentrations in the galaxy are greatest where nucleosynthesis is still occurring. Perhaps it represents sites of star formation, as massive stars tend to be closer to stellar nurseries. Perhaps it represents the regions of gas and dust throughout the Milky Way that obscure gamma rays, much as a photo can represent a silhouette that blocks out background light. Perhaps it represents the scintillations taking place inside the machine that are measured by the photomultiplier tubes. The image could represent all of these things. It could be a perspective on all of these things.

What is required in order to solve this problem is some principled way of drawing a line between *an instrumental perspective* and *the systems in the world the instrumental perspective reveals*. We need to be able to say: *this* set of causal processes constitutes the perspective, and *this* set of causal processes are what is revealed by the perspective. I don't know what grounds there could be for drawing such a line, or what the epistemological significance of the distinction would be. Certainly, nothing in our best scientific theories and models provides any guidance for drawing this line. After all, what distinguishes instruments from the nomological machines found in nature is simply that instruments are human artefacts and we are able to manipulate their parts relatively easily. Instruments are simply other parts of the causal web, but artificial rather than natural. We may have models of the operation of the natural nomological machines, and we may be able to apply such models to draw further conclusions about the world. Consider tree rings. Tree rings are an important source of

evidence for past climate conditions, because tree growth is sensitive to environmental conditions and information about tree growth is preserved in the tree rings. Tree rings are the terminus of a well-ordered, well-understood causal process. I can't see any important epistemic distinction between the use of an instrument like COMPTEL by astronomers and the use of trees by dendroclimatologists. Do trees provides "perspectives" on the climates of the past? Perhaps Giere would accept the massive proliferation of perspectives that this position entails, that any nomological machine counts as a perspective.⁵ Indeed, Giere explicitly treats instrumental perspectives as being determined by human purposes; Giere (2006: 93) writes that instruments "are designed to interact selectively with the world in ways determined by human purposes." This is of course in line with Giere's broader perspectivism, which aims to put human purposes front and centre: his perspectival account of theories and models is built on an agent-based conception of scientific representation (Giere 2006: 60; Giere 2010).

So contrary to what I have suggested, the instrumental perspectivist might be happy to take tree rings or even the Sun to be perspectives. After all, my own argument rests on the claim that instrument can be used and understood only with an instrumental model. Tree rings then can similarly become "instrumental perspectives" when we apply a particular kind of model to them to draw conclusions about past climate conditions. Along similar lines, the instrumental perspectivist can hold that it is our purposes that distinguish an instrumental perspective from the target system revealed by the perspective. There is no fixed line to be drawn; it simply depends on the research project in which the instrument is being used. The output of COMPTEL provides a perspective on nucleosynthesis, as opposed to the decay of aluminium-26, just when it is the former that we are studying.

But before the perspectivist bites the bullet on this one, it is worth emphasizing the damage that this bullet can inflict. It entails that any time we use a well-ordered system in the world to draw a conclusion about something else in the world, the former is a perspective on the latter. It entails that the perspective of an instrument can be defined only relative to a particular scientist at a particular time. After all, two scientists in the same research group might use an instrument for slightly different purposes; and a single scientist might be interested in one process at one time, say aluminium-26 decay, and then a different but connected process at a later time, say nucleosynthesis. At this point, the question arises what work exactly the concept of "perspective" is supposed to be doing. What is the epistemological significance of the claim that any well-ordered system is a perspective, just when we use it to draw inferences about other systems? Once we understand the causal processes involved in a given nomological machine, processes that can be described using the same models by both realist and perspectivist alike, it seems to me that little is gained by describing it as a perspective. I suspect that the inclination is to say: the point of calling all these things "perspectives" is that they are all subject to limitations and distortions, in the sense I have described in the previous section, and so our access to the world is always from a particular point of view, and we cannot "detach" claims about the world from that point of view. Fair enough, but this point is already accommodated by theoretical perspectivism, by a perspectival account of the models that we apply when drawing inferences from particular phenomena (and recall that the instrumental perspectivist needs a perspectival account of these models in order to make sense of the notion that instruments distort).

⁵ I thank an anonymous reviewer for emphasizing this point.

A second puzzle arises when we consider how different perspectives interact. An interesting case that provides a good illustration of this is found in Vertesi (2015), who describes the process of creating images of Mars. The Mars rovers Spirit and Opportunity are both equipped with panoramic cameras, or PanCams; each PanCam has thirteen optical filters. Often scientists will capture several photographs of the same scene, each with a different optical filter. By combining these photographs in different ways, different aspects of the scene are made visible, revealing the various chemical and mineralogical properties of the objects. For the instrumental perspectivist the result is the surface of Mars from the perspective of the PanCam.

However, as Vertesi discusses (2015: 53–72), all images received from the PanCam undergo a calibration process where they are corrected to account for the local conditions on Mars. This is done using a “caltarget”, an object painted with red, green, blue, and yellow sections, and three shades of grey. Since the values for the colours on the caltarget are precisely known, images of it allow scientists to determine exactly how local conditions affect the colours in other images. With the aid of computer analysis, they develop equations that correct for light pollution, scattering, dust, and other conditions in a particular set of photos. Part of the calibration procedure crucially involves humans, since before the computer analysis can occur, humans must highlight different parts of the caltarget image: “the calibrator must identify the different colored zones on the caltarget for the computer, so that the computer can then calculate how much each individual image can be adjusted” (Vertesi 2015: 59). The calibrator must select regions of pixels and tag them as corresponding to specific colour zones of the caltarget. Computers are not yet nearly as efficient at such visual judgements as humans are, so humans are crucial for this stage of image processing.

What is the perspective to which the final output is indexed? If we say that we have an image of Mars from the perspective of the PanCam, we are ignoring all of the other processes involved in image construction, such as the crucial role of computer analysis and human judgement. The humans employ their visual colour perspectives when identifying zones on the caltarget images. These human perspectives are essential for generating the data that scientists use to draw conclusions about Mars. In fact, many of the scientists involved in the Mars mission are interested not in the corrected images but in the calibration procedure itself: as Vertesi notes, atmospheric scientists and soil scientists are often interested in properties of the atmospheric dust, and so “They therefore use the output from the calibration procedure to get dust information and would rather see the dust than the image it obscures” (2015: 78). This output surely can’t be indexed simply to the perspective of the PanCam. Instead, perhaps the output is a product of the PanCam perspective plus the human colour perspective. Or do these combine into a new perspective entirely? Nothing in Giere’s definition of perspectivism or his subsequent discussion rules out combining perspectives to produce novel data. But how do we decide whether we have two perspectives working in tandem, or a wholly new perspective constructed out of two perspectives? It is hard to see how we could go about answering this question – or what difference the answer would make if we found it.

Unless the instrumental perspectivist finds some principled way to answer these problems, then for any instrument, and any output of that instrument, we cannot specify what exactly the perspective of the instrument is. Instrumental perspectivism is ill-defined. It is much more straightforward to think of the instrument as a causal process, as outlined in the instrumental model. To be clear, my goal in the previous two sections

has not so much been to show that instrumental perspectivism is incorrect, but that it is unmotivated. If the theoretical perspectivist is right, then models are perspectival, and this of course includes the instrumental models, but in this respect instruments are no different from any other system we can model. To attempt to apply the notion of perspective to the instruments themselves raises various puzzles. For both realist and theoretical perspectivist, there is a far simpler way of interpreting the situation: we have models of various phenomena, including instruments, and we use those models in addition to our observations to draw conclusions about various systems in the world. The perspectivist then adds a perspectival analysis of all these models.

6 Conclusion

At first blush, instrumental perspectivism seems to be the most plausible form of perspectivism in the sciences. Giere treats it as the less controversial thesis, and as the natural extension of perceptual perspectivism. Closer examination reveals that it is unattractive. Giere defends instrumental perspectivism by appealing to two properties of instruments: partiality and opacity. Partiality is trivial and can clearly be accepted by a standard realist. Opacity is a much more intriguing concept, but seems to conflate transformation of information with distortion of information. Like partiality, transformation is trivial: some sort of transforming process is required in order for an otherwise unobservable property to be made detectable. I take it then that the key claim in instrumental perspectivism is that instruments in some sense distort; it is this claim that allows the instrumental perspectivist to distinguish her view from standard realism. However, an instrument can be said to distort only when there are inaccuracies in the instrumental model, and from this it follows that instrumental perspectivism is dependent on theoretical perspectivism in a way that drains its philosophical significance. Attempting to apply the metaphor of perspective to the instrument itself generates puzzles concerning how perspectives are to be specified.

A key point that I have emphasized throughout this paper is that an instrument is a well-ordered causal process, and in order to draw any conclusions about the world when using an instrument, scientists must understand the instrument in terms of an instrument model that describes how this causal process works. I don't think this is especially controversial; indeed, I think that even the perspectivist would agree with this. But then we can ask: What do we gain by describing the instrument as a *perspective*? What problems does this solve? What does this bring to our understanding of the instrument or the properties it detects? Not much, as far as I can tell. It does however raise various puzzles. Instrumental perspectivism introduces new problems while providing few benefits. Ultimately then, the relative lack of attention given to instrumental perspectivism is, I think, justified: philosophers attracted to perspectivism would do better to explore the prospects of theoretical perspectivism instead.

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Compliance with ethical standards

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