Perspectival Instruments

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Abstract

Despite its potential implications for the objectivity of scientific knowledge, the claim that 'scientific instruments are perspectival' has received little critical attention. I show that this claim is best understood as highlighting the dependence of instruments on different perspectives. When closely analysed, instead of constituting a novel epistemic challenge, this dependence can be exploited to mount novel strategies for resolving two old epistemic problems: conceptual relativism and theory ladeness. The novel content of this paper consists in articulating and developing these strategies by introducing two fine-grained notions of perspectives as the key units of analysis: 'broad perspectives' and 'narrow perspectives'

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Contents

1 Introduction

A scientific instrument is any apparatus, simple or complex, used to investigate the natural world through observation and experimentation.[1] For example, microscopes, cloud chambers, and spectrographs are all scientific instruments through which we can investigate the world. According to the traditional view, the results of investigations undertaken with scientific instruments are not only invaluable for understanding the world around us, but such results are also objective – call this the objective view of scientific instruments.

Opposed to the objective view are two related theses. The first thesis is the theory-ladeness thesis, according to which the background theories, beliefs, or presuppositions of an observer, that is their perspective, may affect their observations (Hanson 1958). The second is the conceptual relativism thesis, according to which there is no ready world that all perspectives can latch

[1] For historical accounts of instruments, see Turner (2013), McConnell (2013), Brenni (2013) and Hackman (1989). For a conceptual classification, see Lauwerys (1937). For definitional discussions on instruments see Warner (1990) and Taub (2019).

onto, instead different perspectives construct the world differently (Kuhn 1962). Both theses represent problematic epistemic challenges in relation to the objective view of scientific instruments. Whilst both problems have been extensively discussed in the literature in relation to observation and experimentation, comparatively few discussions have focussed specifically on scientific instruments, with the notable exception of Chalmers (2003), Heidelberger (2003) and Baird (2004).[2]

In recent years, perspectival realism has emerged as a new view in philosophy of science, opposed to the objective view. Perspectival realism can be understood as a series of views equally committed to the mind-independence of the world and to the situatedness or perspectivity of scientific knowledge (cf. Massimi 2018c, Teller 2011, Giere 2006).[3] As defended by Giere (1999; 2000; 2006), and recently by Evans (2020), perspectival realism holds that scientific instruments are perspectival.[4] I will show that this claim is best understood as highlighting the dependence of instruments on different perspectives. When closely analysed, instead of constituting a novel epistemic challenge, this dependence can be exploited to mount novel strategies for resolving two old epistemic problems: conceptual relativism and theory ladeness. The novel content of this paper consists in articulating and developing these strategies by introducing two fine-grained notions of perspectives as the key units of analysis: 'broad perspectives' and 'narrow perspectives'.[5]

The first strategy is developed to respond to conceptual relativism brought about by 'instrumental incommensurability', understood as a form of discontinuity or incommensurability at the level of the instruments themselves. The strategy is developed around broad perspectives, understood as culturally and scientifically situated theoretical frameworks typical of a scientific community (Massimi 2018c). I show that far from constituting a novel epistemic challenge, the dependence of instruments on broad perspectives, when closely analysed, provides instead the means to mount a novel response to the old epistemic challenge of conceptual relativism.

By recourse to the history and philosophy of science three points are established. First,

[2]See Laudan (1990) for a comprehensive discussion of both problems, and New Experimentalists, such as Hacking (1983), Franklin (1990; 1986; 2015), Mayo (1996), Franklin and Perovic (2019) on epistemic strategies to overcome the theory-ladeness of experiments, and other sceptical challenges.

[3]See Creţu 2020c for an accessible overview.

[4]For more general problems with perspectivism, see Chakravartty (2010), Chirimuuta (2016), and Morrison (2011). For a sustained defence of perspectivism see Massimi (2012; 2018a;b;c;d).

[5]Broad perspectives are discussed by Massimi (2018c) and narrow perspectives are discussed, in different ways, by Massimi (2012) and Creţu (2020a). The current paper builds on and extends these earlier analyses in a systematic way and applied in a new context.

it is established that objectivity standards (cf. Daston and Galison 2007) – which govern the use of scientific instruments – are not tied to any particular broad perspective and thus if they are perspectival they are so in a much broader sense. Second, it is established that when broad perspectives change, objectivity standards do not change concomitantly. And third, by drawing on two brief case studies – the history of the cloud chamber (Galison 1997) and of stellar classifications (Hoffleit 1991) – it is established that scientific instruments and their outputs can cut across both broad perspectives and changing objectivity standards. Thus, as long as shifts in objectivity standards are not abrupt and discontinuous and do not correspond to shifts in broad perspectives, knowledge derived from scientific instruments can be objective despite changes in broad perspectives.

The second strategy is developed around narrow perspectives to respond to the theory-ladeness challenge in relation to scientific instruments. I show that narrow perspectives, which constitute the working stances of scientists, are restricted neither to one theory nor just to theory. As such, narrow perspectives contain within them cross-perspectival justificatory tools to render instruments and their data valid and objective.

This paper will be of value to philosophers, scientists, and historians who take scientific instruments to deliver knowledge about the world. Since the challenges posed by perspectivalist claims threaten to undermine the process of scientific knowledge production, any disruption to the process of using instruments to obtain scientific knowledge is worth investigating in its own right.

The paper is structured as follows: Section 2 examines notions of 'perspective' and clarifies Giere's account. In Section 3 the problem of conceptual relativism is analysed in terms of instrumental incommensurability between broad perspectives. Thus reframed, the problem can be resolved via reference to two novel responses, the first 'objectivity led', the second, 'instrument led'. In Section 4 the problem of 'instrumental theory-ladeness' is separately resolved with reference to individual scientists' narrow perspectives. It is ultimately demonstrated that scientific instruments can be understood as perspectival in two distinct senses, each leading to distinct challenges for which systematic responses are provided.

2 Perspectives Clarified

To determine what, if any, the import of scientific perspectivism is in relation to scientific instruments, and whether in this context it brings about either new epistemic challenges or new solutions to such challenges, two steps are necessary. First, it is necessary to understand what kind of 'perspectives' are relevant to instruments. Second, it is necessary to understand in what ways scientific instruments depend on relevant perspectives and what epistemic consequences may result from such dependence.

2.1 Intuitive Perspectives

Consider, to begin with, two of the most common meanings associated with perspectives: the private, personal point of view and the human point of view. Regarding the first, we interact with the world from our point of view and not from another's point of view and in a deep sense we cannot entirely escape our point of view. Regarding the second, we cannot know from a non-human point of view, and thus, whatever we do know from the human point of view is all we can know. Whilst it is important to acknowledge these limitations, they are nonetheless insufficient insights for a full analysis of the perspectivity of scientific instruments.

The perspectivity of instruments could be further taken to mean something about the way humans 'see' with and through instruments (Giere 1999; 2000; 2006). Not all humans are equipped with the same visual system. Though most humans have trichromat vision which enables them to see the full-spectrum of colours, some humans are colour-blind. Most frequently, colour-blind humans cannot distinguish red and green and in some cases complete colour-blindness precludes the experience of colours. If instruments are perspectival because the results they yield depend on the visual system which manipulates them, their perspectivity might not be trivially true. In and of itself the claim that different visual systems can yield different kinds of knowledge about the world is not epistemically problematic. Suppose Cat and Pat are using exactly the same microscope to look at an insect wing. If Cat cannot see any colours and Pat can, they will naturally see the insect wing differently, Cat from a monochromatic perspective, Pat from a colourful perspective. Their perception of the insect wing will be inherently different, one without colour information, the other with colour information. Thus, due to their different visual systems, Cat's and Pat's investigations with the same instrument can yield different kinds of knowledge about the world. What this example suggests, however, is that the perspectivity under discussion has nothing to do with the instrument in question. Cat and Pat would see the insect wing differently with or without the instrument, since it is their visual system that constitutes the relevant perspective and not anything to do with the instrument itself.

2.2 Scientific Perspectives

We may further assume that what makes instruments perspectival are the following perspectival features: i) "they respond only to a limited range of aspects of their environment" (Giere 2006, p. 41), ii) "even for those aspects of the world to which they do respond, the response is limited" (id.), and iii) they "have some limitations on their ability to discriminate among inputs that are theoretically distinct" (p. 42). Evans (2020) recently discussed the first two features in his account of 'perspectival objectivity' and points of agreement or disagreement will be highlighted below.

The claim that scientific instruments are perspectival because they have a limited range should hardly be controversial. It is simply to say that a scientific instrument will deliver knowledge of only some aspects of the world but not others. This is nevertheless self-evident: every observation from the vantage point of a particular instrument is limited to the range of inputs detectable by the relevant instrument. For example, a telescope is useless for detecting positrons simply because the energy scale of the positrons is not detectable by telescopes. We, as humans, are similarly 'limited' in that "we are sensitive only to a certain set of variables, namely ones that can be detected by sight, sound, touch, and taste" (p. 5) as Evans (2020) points out. This insight, whilst useful, does not seem to fully capture whatever it is that makes instruments perspectival.

The second respect in which instruments can be deemed perspectival is through their limited response to limited inputs. To use Giere's example, "[a] camera responds only to radiation to which its film or more recently, its digital sensors are attuned" (p. 42). Since "[e]very instrument interacts with the world only from its own particular perspective" (Giere 2000, p. 10), and "part of the perspective of any instrument is determined by its built in margin of error" (p. 11), instruments can only yield partial, perspectival knowledge. This, as Evans (2020) emphasises, "is a trivial observation, in the sense that we cannot model undetectable properties or behaviour of a system in terms of undetectable variables" (p. 5). According to Evans, this observation discloses, nevertheless, something about the limitations of the perspective through which we can interact with and model the world. Whilst Evans is right to emphasise that this point exposes the role of our "idiosyncratic capabilities to interact with, and model, reality" (id.), we can only interpret this claim as circumscribing the perspective of the instrument, from, evidently, our own vantage point.[6]

The third respect in which instruments are judged to be perspectival consists in their inability to discriminate between theoretically distinct inputs. Prima facie this may strike one as a misplaced charge since instruments do not have agency and so they are not meant to distinguish between theoretically distinct inputs. But, since Giere insists that "claims about what is observed cannot be *detached* from the means of observation" (Giere 2000, p. 48) and that "[o]ne cannot detach the description of the image from the perspective from which it was produced" (p. 56), the indiscriminateness of instruments is due to their theory-ladeness. Realists, relativists, positivists, and pragmatists alike have long agreed that "theories are involved in the construction and interpretation of instruments" (Laudan 1990, p. 47) and that "theoretical assumptions go into determining the boundary conditions supposed to apply to any situation under scrutiny" (id.). One may nevertheless insist that there is something deeply perspectival about cases of circular theory-ladeness in which the theory of the instrument and the theory of the phenomena are mutually reinforcing. This is a legitimate worry examined in section 4.

The most promising interpretation of the perspectivity of instruments is as highlighting the dependence of instruments on different kinds of perspectives. The personal, the human, and the visual perspectives were diagnosed as bearing little on scientific instruments, whilst additional notions proposed by Giere require further development. In particular, understanding perspectives as "a way of constructing scientific models" (Giere 1999, p. 79) or a particular culture (Giere 2013) make for a useful, yet overly broad, dependence of instruments on such perspectives. Similarly, the standpoint of a scientific community or the observational standpoint of an observer or of an instrument (Giere 2006) make for a rather coarse grained dependence. In the remainder of this paper it will be shown that finer-grained notions, i.e., broad perspectives (Massimi 2018a) and narrow perspectives (Massimi 2012, Creţu 2020a), can be exploited to deliver novel solutions to both conceptual relativism and theory-ladeness.

[6] Baker (2020) offers a similar diagnosis.

3 Broad Perspectives

This section explores the potential benefits of thinking of perspectives as historically and intellectually situated scientific frameworks typical of a scientific community, along the lines of Massimi (2018a). According to Massimi (2018a), such perspectives, let us call them broad perspectives, encompass "(i) the body of scientific knowledge claims advanced by the scientific community at the time; (ii) the experimental, theoretical, and technological resources available to the scientific community at the time to reliably make those scientific knowledge claims; and (iii) second-order (methodological-epistemic) claims that can justify the scientific knowledge claims so advanced" (p. 343). Thus defined, broad perspectives are better thought of not as a specific theory, but as research traditions.[7] Like research traditions, broad perspectives sponsor a variety of norms, background assumptions, 'narrow perspectives', and theories alike, as well as theories about instruments, their operation, and their interpretation.[8]

However, whilst each such perspective can produce through its instruments and their outputs its own conceptualisation of the world, any such conceptualisation can become essentially non-transferrable across broad perspectives, leading to a form of incommensurability – let us call it instrumental incommensurability – which can lead, in turn, to conceptual relativism. In what follows, two novel responses to instrumental incommensurability are offered, an 'objectivity led response' and an 'instrument led response'. But, before we turn to these two responses it will prove instructive to understand how the challenge arises.

3.1 Instrumental Incommensurability

Broad perspectives, understood as research traditions, articulate through the elements they sponsor particular conceptualisations of the world. For example, broad perspectives sponsor objectivity standards, such as 'truth-to-nature' (standardised types), 'mechanical objectivity' (proceduralized automation), 'structural objectivity' (communicable invariance) or 'trained judgement' (skilled interpretation).[9] Briefly, the first objectivity standard refers to the practice of the

[7] This is a gloss on Massimi (2018a), who acknowledges, but does not clarify dissimilarities between historical practices and contemporary modelling practices.

[8] See Laudan (1977) on research traditions and theories, and Creţu (2020a;b) on research traditions, perspectives, and theories.

[9] A broad perspective sponsors or endorses objectivity standards, but it does not necessarily create them.

17th and 18th century natural philosophers to whom the variability of individuals in nature possessed too great a danger for subjective distortion. For them, objectivity consisted in selecting and perfecting an *archetype*, which could *truly* stand for the whole class. This practice declined in popularity around the 1830's (though it did not vanish), with the rise of the second standard of objectivity. The era of mechanical objectivity, extending to the 1920's, sought to recuperate the variability of the individuals through mechanised procedures that would suppress the predecessors's predilection to prettify. Alongside this practice, though in reaction to it, structural objectivity was developed around 1880's. This was a standard which sought to extract only those invariable, structural features that could be communicable to one and all. In reaction to this sanitised objectivity standard and as a result of increasingly complex instrumentation, the 1920-30's saw the emergence of a new standard of objectivity, trained judgement, which relied on the hard won skill of the scientist to detect patterns and to interpret complex families of phenomena.

Each of these objectivity standards was deployed in scientific practice, and specifically in the use of scientific instruments in order to suppress problematic subjectivity in its many guises, from the predilection to "pretify, idealize", distort or project to the tendency to "regularize observations to fit theoretical expectations" (Daston and Galison 2007, p. 34). However, if such objectivity standards turn out to be perspectival (since embedded within a particular broad perspective), this might suggest that instruments and their outputs might themselves be found to be perspectival. Were this scenario to prevail, one might rightly conclude that instruments cannot yield objective knowledge because they are essentially laden to a particular point of view (albeit a broad one in this case). And thus, broad perspectives, like their Kuhnian predecessors, could lead to pervasive Kuhnian "paradigm-ladeness" and further problems thereto.

One particularly thorny problem is conceptual relativism, typically brought about by some form of incommensurability. Conceptual relativism is an old problem for scientific knowledge (cf. Laudan 1990), though not usually concerned with scientific instruments. Let us nevertheless assume that conceptual relativism can be brought about by some form of discontinuity or incommensurability at the level of the instruments themselves – let us call this 'instrumental incommensurability'. If and when broad perspectives change and such change leads to either knowledge of instrument building and operation or knowledge delivered by instruments becoming essentially non-transferable from one broad perspective to the next, the instruments can be said to be 'internal' to that perspective (Giere 2006, p. 49). By specifying in what ways instruments can be said to be internal to a broad perspective and what challenges may arise, we can then show how the relevant challenges can be resolved.

In principle, there are at least three different ways in which instruments can be said to remain internal to a broad perspective and become essentially non-transferable:

a) when there is physical non-transferability of instruments and their outputs across broad perspectives;

b) when non-transferability of technical knowledge occurs, understood as either practical or as theoretical knowledge of instrument-building and operation, or finally,

c) when conceptual non-transferability of instruments and their outputs occurs.

In practice, it is difficult to find examples of radical discontinuity in the history of instruments for the simple reason that it is difficult to find things that were lost. Even the famous astrolabe of the the Hellenistic world of Alexandria, despite being materially lost to later astronomers, resurfaced in medieval Islam through texts and practices (see Hayton 2012 and King 1992). Relatedly, feeding scepticism about radical discontinuity, even musical instruments confined to the history books, such as the Epigonion and the Barbiton of Ancient Greece, have been recently recreated (Avanzo et al. 2010). Nonetheless, it will be instructive to examine the different ways in which instrumental discontinuity can occur in order to identify the attending challenges.

Broad perspectives are extended in time and thus *the physical non-transferability* of instruments, as well as of their physical outputs is unfortunately unavoidable. Instruments may become irreproducible on certain timescales due to lack of material resources or can become obsolete when more efficient alternatives are developed (i.e., less costly, more sustainable etc.). Instruments are also likely to deteriorate, can be moved, can fall into disrepair or fall pray to accidents and natural disasters (cf. Schaffer 2011). All these possibilities can make instruments, as well as their outputs, physically non-transferrable across broad perspectives. This kind of non-transferability, even if seen as some form of broad perspectivity, would nevertheless be entirely accidentally located within a broad perspective. For accidental occurrences that may lead to the destruction of instruments to coincide with the cut-off point of the transition from one broad perspective to another is not only an entirely contingent matter, it is also exceedingly unlikely. If this were nonetheless to occur, it could lead to a form of (radical) conceptual relativism brought about, inter alia, by instrumental incommensurability between broad perspectives. To be precise, since different instrumental perspectives can be said to construct the world differently, any discontinuity between such perspectives may preclude any commonly established facts between the relevant perspectives, leading thus to conceptual relativism. Whilst this is a serious problem for the progress of science, conceptual relativism is neither a distinctively perspectival challenge (but an old Kuhnian challenge), nor is it a challenge specific to, or restricted to, scientific instruments.[10]

Unlike the physical non-transferability of instruments, *the technical non-transferability* of instruments is more likely to occur.[11] Yet, like the physical non-transferability of instruments, technical non-transferability amounts to the same type of Kuhnian challenge, since non-transferability precludes the possibility of commonly established facts (because the facts can no longer be produced, recognised etc.). Thus, whilst one can rightly take the technical non-transferability of instruments as a form of perspectivism, it remains to be shown that this kind of perspectivism is distinctively different from Kuhnian paradigm-ladeness which can be said to lead to conceptual relativism via instrumental incommensurability.

Finally, *the conceptual non-transferability* of instruments and their outputs across broad perspectives constitutes an equally serious problem as their technical non-transferability. If instruments and their outputs are conceptually laden to broad perspectives, then each broad perspective produces through its instruments and their outputs, its own conceptualisation of the world. To put it differently, the non-transferability of instruments and their outputs across broad perspectives means that all knowledge yielded by instruments can only be knowledge from within a perspective. This amounts to a type of perspectivity akin to conceptual relativism. Insofar as perspectivity amounts to conceptual relativism, there is, once more, no novel epistemic import of perspectivity. However, whilst conceptual relativism is not a distinctively perspectival challenge, two distinctively perspectival responses are available in relation to instruments, as will be argued in the remainder of this section.

First, an important clarification is in order. We assumed that objectivity standards are perspectival, that is, that they are specific to a broad perspective.[12] We further assumed that

[10] For an excellent discussion of the intricacies of relativism and different solutions, see Laudan (1990), for an overview see Baghramian and Carter (2019).

[11] See Hicks (2017) on technical discontinuity and Galison (1997) on technical continuity.

[12] This assumption would be warranted within Giere's (2006) perspectivism.

if broad perspectives are regarded as insular and disjointed, then changes in broad perspectives automatically lead to wholesale changes, including changes in objectivity standards, which can bring about conceptual relativism. Yet there are strong reasons to resist our previous assumptions for three main reasons:

i. first, the scholarship on the history of objectivity suggests that objectivity standards are not tied to any particular broad perspective (and thus if they are perspectival they are so in a much broader sense);

ii. second, when broad perspectives change, objectivity standards do not change concomitantly; and,

iii. third, and most importantly, scientific instruments and their outputs typically cut across both broad perspectives and changing objectivity standards.

The first two reasons can be combined to mount a novel 'objectivity led' response to the instrumental incommensurability challenge, developed in 3.2, whilst the third reason guides a novel 'instrument led' response, developed in 3.3.

3.2 Objectivity Led Response

In this section it is shown that objectivity standards are not inherently tied to any particular broad perspective nor do they necessarily change concomitantly with any broad perspective. On the contrary, it is shown that older standards can survive alongside succeeding predominant standards, even past the predominance of the succeeding standard. For example, as Daston and Galison indicate, 'truth-to-nature' survived not only alongside 'mechanical objectivity', but also alongside 'structural objectivity' and 'trained judgement'. Thus, if, as Daston and Galison (2007) suggest, objectivity standards changed first and foremost in response to particular subjectivity threats, such as prettifying, idealizing, distorting, projecting or regularizing observations to fit theoretical expectations, we can reasonably assume that each objectivity standard 'strove' away from perspectivity to apersepctivity. Hence, even if objectivity standards are perceived as in some way perspectival, continuity in objectivity standards over and above changes in broad perspectives, should suffice to avert perspectivism-cum-conceptual relativism in relation to scientific instruments.

Daston and Galison (2007) identify four types of objectivity, each *predominant* in different periods, though each relevant to other notions of objectivity over considerably longer periods of time past their predominance. Truth-to-nature, the first standard of objectivity identified by Daston and Galison (2007), was predominant in the 17th and 18th century. It consisted in identifying idealised types – arrived at through reasoning and selection. Idealised types could not be found in nature, but were taken to be 'truer' to nature than any unruly token. Tokens had fleeting features which had to be brought within an objective type through selection, synthesis, and idealisation. To the 17th and 18th century naturalists' 'unreasoned observations' were considered subjective, whilst the "idea in the observation" and not the observation itself was considered objective, true-to-nature.

The truth-to-nature objectivity standard changed around 1830, giving way to mechanical objectivity which regulated scientific practice for nearly a century. New means of mechanisation and automation promised deliverances of instruments, such as photographic images, uncontaminated by the dangerous distortions of reasoned images. When automation was not possible, exceedingly proceduralized means of recording nature without distortion or interpretation were developed, which often involved "humans acting as will-less machines" (p. 120). Yet, no automated instruments could offer 'pure', unadulterated access to nature. For example, depth of field or colour, could not be precisely recorded by automatic means, leading to accuracy being traded off for mechanical reproduction. The preponderance of such trade-offs, despite automation, left an ineliminable human element which the succeeding image of objectivity, structural objectivity, sought to suppress.

Structural objectivity emerged in the 1880s, co-existed with mechanical objectivity till at least the 1920s, and is still embraced by scientists and philosophers with a structuralist bent today. Structural objectivity, which must be "communicable to all" and according to which the "private mental world of individual subjectivity" (p. 254) has no place in the epistemology of nature, is not always applicable to instruments, except maybe for logic devices such as counters, spark chambers, and wire chambers (see Galison 1997 for details on logic devices). This is because structural objectivity is primarily concerned with "enduring structural relationships that survived mathematical transformations, scientific revolutions, shifts of linguistic perspective, cultural diversity, psychological evolution, the vagaries of history, and the quirks of individual physiology" (p. 259), and not, strictly speaking, with the deliverances of instruments. Whilst not pertaining directly to instruments, structural objectivity is worth bringing into the present discussion for it was concurrent with mechanical objectivity and it neither occurred nor shifted concomitantly to broad perspectives.

Structural objectivity proved insufficiently versatile for understanding complex families of phenomena and thus a new form of objectivity, trained judgment, became predominant between mid- to late twentieth century. Trained judgment was needed to "synthesise, highlight, and grasp relationships" and to "smooth, refine, or classify images" (p. 314). In stark contrast with both mechanical objectivity and structural objectivity, which sought to extirpate individual judgment, trained judgement relied on an individual's ability to "read, to interpret, to draw salient, significant structures from the morass of uninteresting artifact and background" (p. 328). Trained judgment relied on the human ability to 'seize pattern' and to obtain 'knowledge at a glance', skills that were "acquired through a sophisticated apprenticeship" (p. 331). Interpretation, previously conceived as epistemically problematic and as stunting the effort to 'get at the world', was now conceived as necessary to interpret ever more complex images produced by sophisticated instruments.

Thus, as the history of objectivity distinctly indicates, there is no abrupt shift from one standard of objectivity to the next. In fact, two or more standards of objectivity survive alongside one another, whilst the transition from one standard to another is clearly traceable. Unlike the traditional Kuhnian narrative of wholesale paradigm-changes, shifts in objectivity standards are not wholesale. Not only does each type of objectivity safeguard against specific types of subjectivity and thus screens off epistemic threats such as "drowning in details, of burking a fact to support a theory, of being straitjacketed by mechanical procedures" (p. 377), all of which are "genuine dangers to knowledge" (id.). But, each objectivity standard builds on and reacts to earlier specific threats to knowledge. Therefore, as Daston and Galison (2007) suggest, it "is a misconception, albeit an entrenched one, that historicism and relativism stride hand in hand" (p. 376).

If one accepts Daston and Galison's (2007) history of objectivity, another important observation becomes salient: objectivity shifts do not correspond to shifts in broad perspectives. For example, Lorentzian ether theory and special relativity can both be said to be governed by structural objectivity, despite being different broad perspectives (for the history of special relativity and Lorentzian ether theory, see Brown 2005). Similarly, trained judgment governed cloud chamber experiments both prior to and post the crystallisation of relativistic quantum mechanics (Creţu 2020a, Roqué 1997). Scientists, in such cases, successfully navigated not only shifts in broad perspectives but also later shifts in objectivity standards (Galison 1997). What the history of objectivity demonstrates is that conceptual relativism can be avoided with respect to scientific instruments as long as shifts in objectivity (a). are not abrupt and discontinuous and (b). do not correspond to shifts in broad perspectives. Thus, knowledge derived from scientific instruments can be objective despite changes in broad perspectives.

What if broad perspectives are broader?[13] That is, what if the objectivity standards themselves define the perspectives, and when they shift, the instruments and their deliverances also shift? To be clear, the critic may insist that the objectivity led response leaves open the possibility that instrumental incommensurability occurs when objectivity standards shift. Drawing on Galison (1997) and Hacking (1983), who have presented detailed case studies involving instrument led continuity despite changes in theory, a novel answer that demonstrates instrument led continuity despite changes in objectivity standards is offered in the next section.

3.3 Instrument Led Response

The second response to instrumental incommensurability resides in the fact that instruments and their outputs typically do not change when objectivity standards change. To be clear, the claim is that when objectivity standards shift, scientists who adhere to the new predominant standard can nevertheless use instruments designed according to previous objectivity standards. Importantly, the outcomes of such instruments are not typically contested either. This is not to say that in some cases instruments and their datum may not lose their original significance or the datum may not be interpreted differently. This can of course occur, but typically, the datum stays the same (cf. Ackerman 1985, p. 33). To illustrate this claim, let us consider two brief examples.

The first example, drawn from physics, is primed to illustrate the fact that instruments and their deliverances can be markedly cross-perspectival, even when perspectives are defined by the objectivity standards themselves. That is, despite being built or used to deliver data under the auspices of one objectivity standard, the instrument and the data produced, often

[13] Thanks to Nicos Stylianou for very useful discussions on this issues and for pushing me to clarify this point.

successfully survive shifts in objectivity standards. The cloud chamber, constitutes one example of an instrument spanning a lengthy and versatile career through shifting objectivity standards. The cloud chamber is undoubtedly one of the most important instruments of the 20th century.[14] It played an important role in many Nobel Prizes in physics and it gave rise to the tradition of 'golden events' – that is, the tradition of making visible and capturing on film the interactions of sub-atomic phenomena.[15]

The cloud chamber was invented by C.T.R. Wilson in 1911 under the sponsorship of mechanical objectivity. Whilst pursuing research in atmospheric phenomena, Wilson recorded the first golden event, of an alpha ray, in 1911. The cloud chamber, though developed by Wilson for the study of atmospheric phenomena, was soon appropriated by the Cavendish physicists to study sub-atomic phenomena. After a series of tweaks and improvements, the cloud chamber gave rise to further golden events, such as the photograph of the positron published by Carl D. Anderson in 1932 and the joint discovery of the muon by Anderson and Seth H. Neddermeyer in 1936. The tradition of golden events, inaugurated by C.T.R. Wilson under the auspices of mechanical objectivity, gathered momentum under the sponsorship of trained judgment with Anderson's discovery of the positron, and it is still very much alive almost a century later, and in spite of various changes in objectivity standards. Importantly, neither C.T.R. Wilson's photograph of alpha rays, nor Carl Anderson's photograph of the positron have lost their significance, nor have Wilson's cloud chamber or Anderson's cognate apparatus been called into question. These photographs were produced from the vantage point of perspectives governed by objectivity standards different from those which originally governed the invention of the cloud chamber and were embedded within successive broad perspectives governed by yet different objectivity standards. Thus, what we can learn from the history of the cloud chamber is that changes in objectivity standards have not transformed or denied the significance of either the cloud chamber itself or of its capacity to produce golden events. To put it differently, its ladeness to different norms of objectivity did not bring about conceptual relativism via instrumental incommensurability. On the contrary, it is clear that the use and importance of the cloud chamber cuts across both broad perspectives and changing objectivity standards and it is thus markedly cross-perspectival.

[14] The historical details are drawn from Galison (1997), Das Gupta and Ghosh (1946), and Blackett (1960).

[15] See Staley (1999).

The second example, drawn from astrophysics, focusses on the data, rather than the instruments per se. It shows that even when certain instruments become obsolete, their deliverances retain their original authority despite shifts in objectivity standards. The example concerns the photographic plates of the spectra of stars that became available towards the end of the 19th century with the invention of the spectroscope.[16] By attaching a prism or a slit to a telescope to separate the rays of starlight by their wavelength, their unique spectra or absorption lines can be recorded and their brightness can thus be measured. The first successful attempt to photograph the spectra of stars belongs to Henry Draper, who photographed the spectrum of Vega in 1872, with similar research also being conducted by William and Margaret Huggins.

Henry Draper's photographic plates were analysed and measured by Edward C. Pickering and the 'human computers' working alongside him at the Harvard Observatory, Williamina Fleming, Antonia Maury, and Annie Jump Canon.[17] This analysis constituted the catalyst for the creation of the Henry Draper Memorial which gave rise to the Draper Catalogue of Stellar Spectra, first published in 1890 by Pickering and Williamina Fleming, with subsequent instalments in 1897 from Antonia Maury, and in 1901 from Annie Jump Cannon. The Draper Catalogue of Stellar Spectra constitutes the first modern classification of stars and is the forerunner of both The Henry Draper Catalogue (published between 1918 and 1924 by Annie Jump Cannon)[18] and of Morgan, Keenan, and Kellman's 1943 Atlas of Stellar Spectra.

Importantly, for our purposes, the Henry Draper Catalogue was designed according to the canons of mechanical objectivity, which was quintessentially empirically driven and implied 'automation' and abstention from theory, whereas the Morgan, Keenan, and Kellman's Atlas of Stellar Spectra relied on trained judgement, skill, and interpretation. Yet despite the use of mechanical objectivity, the results of the Henry Draper Catalogue were not only fully understood and recognised by their successor, but the spectrographic photographs on which it was based preserved, in bulk, their significance. Although Morgan, Keenan, and Kellman used different instruments, published new photographs, and operated with a distinct objectivity standard which relied on their skill and interpretation, i.e., trained judgement, they nevertheless cite the Draper Catalogue as the direct forerunner of their own classification (cf. Morgan et al. 1943, see

[16]The historical details are drawn from Hoffleit (1991).

[17]Human computers are scientific workers who performed calculations or reduced and analysed data before the advent of electronic computer, for details see Light (1999).

[18]Two other extensions, the Henry Draper Extension, published between 1925 and 1936, and the Henry Draper Extension Charts, first published in 1937, were assembled by Annie Jump Cannon and Margaret Mayall.

also Daston and Galison 2007). The spectrographic photographs which constitute the basis of the Henry Draper Catalogue of Stellar Spectra can thus be said to cut across shifting objectivity standards. What this example suggests then is that changes in objectivity standards did not lead to conceptual relativism brought about by instrumental incommensurability.

Two examples cannot conclusively show that instrumental incommensurability cannot occur or that it does not lead to conceptual relativism when objectivity standards shift. Reflecting on these examples suggests nevertheless that conceptual relativism can be avoided when instruments and their deliverances survive shifts in objectivity standards. Moreover, conceptual relativism via instrumental incommensurability can also be avoided when shifts in broad perspectives do not correspond to objectivity standards shifts. Thus, instead of constituting a novel epistemic challenge, the dependence of instruments on broad perspectives, when closely analysed, provides instead the means to mount a novel response to the old epistemic challenge of conceptual relativism.

To sum up, it was shown that not only are objectivity standards and broad perspectives not concomitantly shifting, but instruments and their deliverances can cut across both broad perspectives and objectivity standards. So whilst objectivity standards and instruments are in some respects perspectival, by being historically and intellectually situated both within and outside broad perspectives, they are equally cross-perspectival. Thus, the scientific instruments themselves, and the objectivity standards governing them, equally constitute tools to block conceptual relativism brought about by instrumental incommensurability.

4 Narrow Perspectives

This section examines the nature of the dependence of instruments on 'narrow perspectives', the resulting problem(s), and a potential solution. Narrow perspectives, unlike broad perspectives, have a significantly restricted scope. However, they are not restricted to a single theory or model. Narrow perspectives are distinctively *perspectives or points of view*, unrestricted to any particular theory (Creţu 2020a) or just to theory (Massimi 2012). Narrow perspectives can be understood as "sophisticated theoretical framework[s] that encompasses the set of theoretical interests and background theoretical knowledge (principles and assumptions equally) that a researcher or group of researchers can be said to hold at any given time" (Creţu 2020a, p. 29). Or a narrow perspective can be constituted by a scientist's epistemic perspective which includes beliefs about the phenomena under investigation, the correct functioning of instruments and the validation of their outputs, but also more general beliefs about their "perceptual system, cognitive faculties, measurement devices, and their reliability as sources of belief" (Massimi 2012, p. 41). Either notion of perspective characterises the working stance of a scientist, who, in one capacity or another, comes to have a bearing on scientific instruments, directly by constructing or using them, or indirectly by affecting the data. Since the use of scientific instruments can become thus laden to a scientist's (narrow) perspective, elucidating the nature of the ensuing ladeness will prove highly instructive.

4.1 Instrumental Theory-Ladeness

This section offers an explication of the relationship between instruments and theories to show that reliance on theory is for the most part invaluable to using instruments and interpreting their data. However, complications arise once scientists' (narrow) perspectives are taken into account leading to 'instrumental-theory-ladeness'. This variation of the theory-ladeness challenge is explained in this section and a solution is proposed in the final section.

Scientific instruments may become laden to a scientist's viewpoint in a variety of ways. Theory-ladeness can occur i. in cases where the theory governing the instrument and the theory of the phenomena are one and the same, ii. in cases where there exists an over-attachment to the theory that clashes with the recalcitrant data produced by an instrument, or iii. it can occur as a result of practical problems, such as "experimental design, failure to interpret observations correctly, possible experimenter bias, and difficulties in data acquisition" (Franklin 2015, p. 155).

In the first case theory-ladeness is avoided by ensuring that the theory governing the instrument and the theory of the phenomena are different. As Franklin argues, "no obvious problems arise for the testing of the theory of the phenomena" in such cases (Franklin 2015, fn. 8, p. 439). And, even in cases in which the theory governing the instrument and the theory of the phenomena partially overlap or overlap to a large extent, successful strategies for overcoming vicious circularity have already been suggested in the literature. For example, as early as three decades ago, Franklin et al. (1989) discussed the possibility of using an instrument whose operation depends on the same hypothesis as that of the phenomena under test and suggested that in such cases the calibration of the instrument should suffice to mitigate the threat of vicious theory-ladeness. The instrument under test would be independently calibrated against an already validated instrument, by measuring a different phenomena whose theory overlaps with neither instrument. Later, Chalmers (2003) offered a detailed case study of the electron microscope, showing that in spite of a deep theory-ladeness, instruments could nevertheless be used to collect data about phenomena, even in cases where the theory of the phenomena was involved in the use of the instrument. As Chalmers notes, "[t]he interdependence of theory and data [...] can, in appropriate circumstances, be exploited in a way that confounds rather than aids the sceptic" (p. 494). Recently, Beauchemin (2017) showed that in the case of conglomerate instruments such as the ATLAS detector at the LHC, theory input may be essential to confer epistemic value to certain measurements.[19] In fact, "theory-ladeness of measurement is necessary for [measurements] to constitute observations" (p. 309), and often, progress in high energy physics can only be made by mutually adjusting theory and experiment. The same point, though for the case of astrophysics and cosmology, was also made by Bondi (1955), who notes that "[t]o derive any significant astronomical result from the blackening of a photographic plate or the simple reading of a meter a tremendous amount of intervening work has to be done. Corrections may have to be applied, calculations and reductions may have to be carried out, and above all interpretations requiring a great deal of theoretical background may have to be made" (p. 157).

The main point to note in connection to these examples is that once we examine more closely the relevant theory-ladeness of an instrument it becomes clear that the import of theory is for the most part invaluable and not particularly problematic. To be clear, the claim is that regardless of how multiply perspectival the process of using instruments can become – from using a thermometer, to using an electron microscope or a spectrograph to conglomerate instruments such as the ATLAS detector at the LHC – there are epistemic strategies for avoiding vicious theory-ladeness. Insofar as such epistemic strategies can be deployed, instruments remain an objective source of knowledge about the world.

Concerning the over-attachment to the theory that clashes with the recalcitrant data produced by an instrument, a novel complication arises in relation to scientists' (narrow) perspectives. The idea is that scientists' (narrow) perspectives will typically play an important role in accepting new data or in discarding it. For example, if the data is unexpected, "scientists with different perspectives may respond differentially to the same empirical knowledge,[...] impeding

[19]Thanks to Antonis Antoniou for pointing me to Beauchemin's work.

[the] authentication" of some hitherto unknown phenomena (Creţu 2020a, p. 2) and leading to disagreement. In such cases, regardless of the route taken to resolve the disagreement, scientists' (narrow) perspectives inadvertently affect the use of the instruments and the interpretation of their outputs.

Scientific instruments are not only dependent on theory or just one theory, they are also dependent on laws and background conditions, sometimes weather conditions, they are embedded within experiments, and experiments themselves can be theory-laden in a variety of ways, as was recently argued, in different ways by Karaca (2013) and Schindler (2013).[20] When a scientist responds to recalcitrant data they may be objecting to any of the several elements involved in the use of an instrument and the production of the data. Importantly, in accepting or discarding the data, the scientists who interpret the data may call into question the instruments themselves, despite the lack of any obvious practical problems, such as "experimental design, failure to interpret observations correctly, possible experimenter bias, and difficulties in data acquisition" (Franklin 2015, p. 155). To understand why a scientist may accept or reject specific data, we need to understand their narrow perspectives. That is, we need to understand in which ways their assumptions or interests interact with the instruments and the data. This complex relationship between instruments and the production of data and narrow perspectives adds very specific extra layers of theory-ladeness and constitutes a distinct variation on previously acknowledged forms of theory-ladeness. Let us therefore call it 'instrumental theory-ladeness' and consider a possible response to it in the final section.

4.2 Perspectivity Led Response

The claim that instruments are perspectival derives in large measure from the observation that in the construction and use of instruments and the interpretation of their data there are multiple layers of theory involved. This is not particularly surprising since nearly no scientific instrument, if any, ever delivers unadulterated access to incontrovertible facts (Bondi 1955). Some philosophers, such as Giere (2006), have nonetheless taken this perspectivity of instruments to mean that they cannot deliver objective empirical knowledge. However, the fact that theory-ladeness can lead to vitiated results does not mean that it inevitably does so. In this section a more positive interpretation to this challenge is provided by means of explicating the heuristic role of

[20] See also Franklin and Perovic 2019.

narrow perspectives.

In the first instance it will be useful to clarify what kind of perspectivity can be involved in the theory-ladeness of instruments, specifically in relation to a scientist's (narrow) perspective and when and why the resulting perspectivity might be problematic. In talking about a scientist's perspective we can and we often do distinguish between on the one hand, their prejudices, idyiosyncracies, and other subjective elements of their perceptual systems and cognitive faculties and, on the other hand, their background knowledge and theoretical interests. The former is their subjective perspective, the latter is their (narrow) epistemic perspective. The subjective perspective of a scientist cannot be entirely eliminated from the scientific life, but there are many variegated levels of correcting for the ills of subjectivity. The adoption of a standard of objectivity is one way through which subjectivity can be kept in check (as shown in section 3). Another way to correct for subjectivity is to identify and analyse the scientist's narrow perspective, to check their methods and justifications in relation to instruments.

Narrow perspectives can encompass both entrenched background assumptions, as well as less entrenched ones pertaining to particular problems salient to working scientists (Creţu 2020a, p. 32). Furthermore, narrow perspectives enable scientists to "self-reflect on [their] beliefs, on the sources of [their] beliefs, the way beliefs cohere with one another, no less than the way in which they, individually and jointly, are anchored to the empirical ground via reliable methods" (Massimi 2012, p. 49). By examining a scientist's (narrow) perspective, we gain access to their methods, reasons, and justifications for building a particular instrument, using a particular instrument, or interpreting the results of a particular instrument in a specific way. Such knowledge allows us to ascertain what epistemic strategies have been used to avert the dangers of vicious theory-ladeness or the ills of subjectivity, such as making observations fit theoretical expectations.

We usually find that strategies such as those identified by the New Experimentalists (see fn. 2) have been applied to ensure the results of an experiment are accurate and reliable, are to be trusted with a high degree of certainty, even though they cannot ever be absolutely certain. Such strategies as identified and discussed by Franklin (1989), where some pertain directly to instruments, whilst others pertain more generally to experiment include: i) experimental checks and calibration in which the apparatus reproduces known phenomena or reproducing artifacts that are known in advance to be present; ii) intervention, in which the experimenter manipulates the object under observation; iii) independent confirmation using different experiments; iv) elimination of plausible sources of error and alternative explanations of the result; v) using the results themselves to argue for their validity; vi) using an independently well-corroborated theory of the phenomena to explain the results; vii) using an apparatus based on a well-corroborated theory; viii) using statistical arguments.

Strategies such as these are embedded within a scientist's (narrow) perspective and can protect them against their subjective perspectives. Whilst such strategies do no entirely eliminate the threat of subjectivity or vicious instrumental theory-ladeness, they go a long way in safeguarding instruments and their deliverances against this threat. And importantly, such strategies ensure that instruments can deliver objective empirical knowledge about the world.

Besides ensuring that scientists' subjective perspectives are kept in check, narrow perspectives play an additional role. Within a broad perspective, scientific disagreements, especially concerning the results delivered by a scientific instrument can occur more or less frequently. This may be because scientists who work within the same broad perspective, operate with the same objectivity standards, and towards resolving the same empirical or conceptual problem, may nonetheless have very different narrow perspectives. By identifying the differences amongst their assumptions, interests or methods, disagreements can ultimately be resolved or dissolved (cf. Creţu 2020a). The distinction between 'narrow perspectives' and 'broad perspectives' thus facilitates not only the separation of distinct modalities in which instruments can be said to be perspectival, but it is also invaluable for understanding how and why disagreements can occur even when we hold broad perspectives and objectivity standards fixed. Conversely, the fact that scientists may disagree whilst sharing broad perspectives and objectivity standards, owing to their different narrow perspectives, offers a common basis for exploring a constructive resolution of the relevant disagreement.

Narrow perspectives and broad perspectives operate on a different scale. Narrow perspectives concern the running of particular experiments, the operation of specific instruments, and the interpretation of specific data. In contrast, broad perspectives concern the development of a multitude of different narrow perspectives over a significant period of time. Narrow perspectives are more specialised and embed richer, more specific resources for justifying why we have good reasons to use a particular instrument, why the instrument is working properly, why the data it delivers is reliable, why disagreements occur, and how disagreements can be resolved or dissolved. And, they can embed distinctively non-perspectival epistemic strategies to overcome instrumental theory-ladeness that are neither specific to a broad perspective, nor governed by specific objectivity standards, but which instead are more broadly embedded within the epistemology of science. Thus, the epistemic checks which can ensure the reliability of instruments and their data are 'internal' to neither a narrow perspective, nor to a broad perspective, that is, if they are perspectival, they are so in a very broad sense.

To sum up, in this section it has been shown that narrow perspectives have a dual nature in that they can both undermine and vindicate the use of instruments, the data they produce, and the knowledge engendered within both. To be precise, it was shown that when instruments are considered in their complexity both on their own and within the web of experiments, there are many sources of theory input, many possibilities of error, many strategies for overcoming error, and many inputs from the phenomena or the world too. When we say that 'instruments are perspectival' it must be clear what sort of dependence we have in mind and whether this is problematic or not. Merely identifying a generic sceptical worry does not on its own constitute a specific challenge to the epistemology of instruments and experiments.

5 Conclusion and Prospectus

This paper investigated the possible interpretations of the perspectivalist diagnosis that 'instruments are perspectival'. Some interpretations were found to be insightful, but insufficiently developed, whilst others were identified with two well-known epistemic problems, conceptual relativism and theory-ladeness. Through the scholarship on objectivity and the history of canonical instruments (e.g., the cloud chamber), new perspectivalist solutions to the two well known problems were developed. It was shown that conceptual relativism can be averted when objectivity standards governing broad perspectives do not change concomitantly with broad perspectives, and when there is instrumental and data continuity from one broad perspective to the next and despite changing objectivity standards. Such continuity was demonstrated through the use of concrete examples drawn from the history of science. Regarding theory-ladeness, it was shown that this challenge is at the same time far more complex and far less problematic than previously assumed in relation to instruments. The novel response to this problem was to show that it can be more fruitfully analysed in terms of narrow perspectives which allow a closer examination of potential sources of justification and error, and which can constitute the key to understanding and resolving disagreements.

A compelling avenue for future research is to investigate the degree to which the described solutions bear out in realms of science increasingly dominated by the digital computer. Such a task would require, amongst other things, an extension of the scholarship on objectivity, the identification of clear cut cases where the digital computer acts as an instrument, as well as a better understanding of the relationship between digital computers and broad and narrow perspectives. Further, it would be important to determine whether the digital computer is a natural extension of traditional instruments, leading to the same problems, to which the same solutions apply. Or, whether new problems and solutions might require an even finer grain of perspectivism.[21]

[21] The versatility of the digital computer (Parker 2010) is indicated by the fact that it can be involved not only in data production, but also in data analysis or the set-up of an experiment. Equally relevant is the complexity of computer simulations (Morgan and Morrison 1999, Humphreys 2004, Winsberg 2010, Morrison 2015).

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