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12 The Labour of Handwork in Astronomy

Between Drawing and Photography in Anton Pannekoek

Omar W. Nasim

Abstract

This chapter discusses the crucial role of handwork in historical practices of astronomical representation, focusing particularly on Anton Pannekoek's Milky Way drawings. Using a range of cases, it explores how the acts of seeing, knowing, and drawing interacted to benefit observers, especially as a form of scientific labour. This functions as background for understanding the role of drawing and photography in Pannekoek's graphical work. This paper activates the notion of handwork in relation to labour to make it historically relevant for astronomy's representational practices, but also to connect these to broader political and epistemological trends. It will be shown that Pannekoek's emphasis on manual labour acted as a bridge between photography and drawings, and more generally, as an important cross-over point between Pannekoek-the-socialist and Pannekoek-the-astronomer.

Keywords: Anton Pannekoek, socialism, labour, astronomy, drawing, photography, practice

Anton Pannekoek (1873-1960) was a socialist thinker and an astronomer, making major contributions in both domains. However tantalizing this combination might be for a historian of science, it remains to be seen how exactly these two sides of Pannekoek's life might have productively interacted. One of the challenges is that Pannekoek seems to have kept both sides separate and even wrote two different memoirs, one for Pannekoek-the-astronomer and the other for Pannekoek-the-socialist. A reason, perhaps, why he chose

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to duplicate himself in this way, was that his socialism occasionally hindered his astronomical career; while his status as a professional astronomer was used against him in political and ideological disputes. And it does not help that these different sides of his life and work continue to be separated even in subsequent, scholarly works on Pannekoek. All this makes it difficult to see how these sides can be recombined so as to be fruitful to the history of science – difficult, perhaps, but not impossible.

One possibility for connecting the two halves of Pannekoek's oeuvre has recently been proposed by Chaokang Tai. He attempts to connect a particular kind of radical Marxist philosophy of mind to the epistemic virtues underpinning Pannekoek's astronomical research.¹ Though Tai's thoughtful approach yields important results, and has inspired what follows, I propose another alternative, one which focuses not so much on a theory of mind as on hands and tools. I argue that there is a strong, operational presence of the hand in both Pannekoek's astronomical work and in his socialist theories about human development. After all, the significance of the human hand for Pannekoek is immediately gleaned from both his socialist theories and in his representational preferences in astronomy, especially when it came to depicting the Milky Way – a research pursuit that engaged him for most of his life. I claim that what reconnects the two sides of Pannekoek is the astronomical labour connected to *handwork*. The labour and business- or factory-like character of nineteenth-century astronomy, particularly in large, national observatories, has been examined in previous studies.² But the idea of handwork, as instanced in the case of Pannekoek, permits us to extend the useful notion of astronomical labour further into the representational practices of astronomy, like drawing and photography. Each medium will be approached as different but related forms of labour that are linked to the production of knowledge. From this perspective, both drawing *and* photography reveal their productive character as handwork *and* technology. In fact, this approach to Pannekoek will elucidate how labour and handwork related to astronomical practice are implicated in photography; and, on the other hand, how paper and pencil, ink and pen, used in handmade drawings, are technologies in their own right. And all this, thanks to handwork, which acts as a bridge between different media but also between Pannekoek-the-socialist and Pannekoek-the-astronomer.

The first section of this paper summarizes the salient features of Pannekoek's socialist theory of human origins and development. Among the features

1 Tai 2017; see also Tai and van Dongen 2016.

2 Schaffer 1988; Ashworth 1994; Smith 1991.

that will be important for us are the ways in which the labour of hands and tools functioned, socialist thinkers argued, to give rise to the human being, history, science, and technology. But another salient feature is how handwork was thought to overcome ideology and metaphysics, and the dualisms that these are based upon. This section sets the scene for the role of the hand in Pannekoek's socialist framework and for his astronomical practice. In the second section, I aim to motivate what it means for there to be handwork in astronomy. The same section will provide a few cases from nineteenth-century astronomy for understanding the labour involved in the handwork of drawing difficult celestial objects. This is important to do, because, as we shall see in section three, Pannekoek's own astronomical practices are replete with hand-drawings of all kinds, despite the availability of photography, leaving us with the question: why did he not employ photography instead? Section four outlines the broader context for understanding photography's relationship to astronomical labour. It is in the concluding section of this paper that I offer remarks about how handwork acts as a bridge between photography and drawings, a fact that will only go to reinforce how handwork, more generally, acts as an important cross-over point between Pannekoek-the-socialist and Pannekoek-the-astronomer. With my focus on the hand, I do not want to claim that its role is the one and only key to a reunified picture of Pannekoek's oeuvre. Rather, what I offer is a modest proposal about a common feature to both sides of Pannekoek's life and work; which also happens to have implications for how we view astronomical labour especially in relation to representational practices like drawing and photography.

I

Before we come to see how astronomy and socialism might be connected in Pannekoek's unique career, we need to see how he understood the connections between Darwinism and Marxism. Doing so, will lead us directly to the significance of the hand in Pannekoek's worldview. As general theories, Darwinism and Marxism apply to two different domains, but they can nonetheless complement one another in important ways. As a card-carrying socialist, however, Pannekoek was quick to notice that Darwinism had previously been used to justify a particular view of society that opposed socialism, especially in the guise of Social Darwinism. In order to understand, therefore, how these theories relate, Pannekoek begins by addressing the purported misuse of the theory of evolution by social darwinists like Ernst Haeckel and Herbert Spencer, who take the theory of evolution as a justification of

the status-quo authority of the petit bourgeoisie and capitalism. The great mistake all 'bourgeois Darwinists' make, according to Pannekoek, is to incorrectly take a theory that is appropriate and applicable to one domain (the animal kingdom) and uncritically apply it to another (the social world of the human being). Pannekoek believes that this is a category mistake, because human beings have unique characteristics that set them apart from the rest of the animal world. By recognizing these peculiarities, we can also begin to appreciate the importance of maintaining two separate domains: one for Darwinism and the other for Marxism.³ And in distinguishing the different domains of application, we can, it should be noted, accept Darwinism without having to give up Marxism. The two, writes Pannekoek, 'supplement each other, in the sense that, according to Darwinian theory of evolution, the animal world develops up to the stage of man, and from then on, that is, after the animal has risen to man, the Marxian theory of evolution applies'.⁴ Each of these theories explain features of two distinct domains – the animal or human worlds – while remaining continuous and complementary.

But what exactly differentiates the human world from the animal? In answering this age-old question, Pannekoek puts forward the usual suspects: language, society, and abstract thought. However, the crucial driver of human development is uniquely adopted hands, conducive to the use of tools. It is by means of his hands, for example, that 'primitive man, at his lowest stage', distinguishes some objects as tools that assure his survival. As tools begin to vary in complexity and application, 'primitive man' begins to discern different kinds of objects, no longer treating the world as 'a single unit', as do animals.⁵ Being so important to his survival, these tools are designated by sounds and thus named in some primordial language, and in this way, they are shared and their memory passed on. We have already moved from the hand to tools to language. Consciousness appears when the new being distinguishes not just between tools and objects, but also different sorts of intentions manifested in different functions, permitting the development of tools that are ever more task-oriented and refined. But at the same time, the development of more refined tools makes thought itself more nuanced. There is therefore a progressive 'circuit' between material and mental development in the human being – it is this circuit that contributes to human progress, even up to our own day, according to Pannekoek.⁶

3 Pannekoek 1912.

4 Pannekoek 1912, 33.

5 Pannekoek 1912, 49.

6 Pannekoek 1912, 46.

Central to the human hand and its associated tools is the idea of labour, which lies at the heart of this story of progress. It is ‘by his labour’, writes Pannekoek, ‘[that] the primitive ape-like man has risen to real manhood’.⁷ It should be noted that Pannekoek was not alone in arguing for the key role played by labour in the very origins of the human being. We find something very similar in others, like Ludwig Noiré and Frederik Engels.⁸ In fact, this is just one of the many ways in which Pannekoek echoes Engels, who, in an unfinished work, *The Part Played by Labor in the Transition from Ape to Man* (1876), argued that ‘labour created man himself’;⁹ while labour itself emerged with the making of tools. It is in this way that for Engels the hand is central to any story of the development of the human, for ‘the hand is not only the organ of labour, *it is also the product of labour*’.¹⁰ Labour, for both Engels and Pannekoek, is what propels history forward.

Pannekoek, furthermore, takes up the theme of the hand as the organ of labour in order to argue that while Darwinism applies to animal organs, it does not apply in the same way to the ‘artificial organs of men’, which has its own unique laws of development and progress (i.e., Marxism). Darwinism and Marxism can thus be further contrasted when one considers the temporal domains of each: In the case of the former, the continuous evolution in the animal world is ‘infinitely slow, as dictated by biological laws’. In the case of Marxism, on the other hand, human tools ‘can be transformed quickly, and technique makes such rapid strides that, in comparison with the development of animal organs, it must be called marvelous [sic]’. The artificial organs of the human being, i.e. tools, are ‘free from the chain of biologic laws’.¹¹ And just as in the case of the animal, organic world, progress – however rapid – in human tools is actually the result of a struggle that leads to the ‘ever greater perfection of tools’ such that ‘[t]hose races whose technical aids are better developed, can drive out or subdue those whose artificial aids are not developed. The European race dominates because its external aids are better’.¹² Pannekoek observes that although each theory applies differently to their respective domains, Marxism and Darwinism actually share ‘the same principle [which] underlies both theories’; namely, the survival of

7 Pannekoek 1912, 50.

8 The hand has also been of interest in more recent times to, see: Napier 1970; 1980; Wilson 1998; McGinn 2015. The last, though an essay in ‘philosophical anthropology’, meant to be a ‘hymn’ to the hand, does not cite, let alone engage with the ideas of Engels, Noiré, nor Pannekoek.

9 Engels [1876] 1950, 7.

10 Engels [1876] 1950, 9; emphasis in the original.

11 Pannekoek 1912, 51.

12 Pannekoek 1912, 53.

the fittest – it is, in fact, the warrant for technological determinism but also imperial expansionism.¹³ But, unlike capitalism (the bedbug of Social Darwinism), which according to Pannekoek creates a world that resembles the ‘rapacious’ animal world, socialism aims rather to externalize these struggles out towards Nature and away from ‘our own kind’.¹⁴

The hand therefore represents more than just an organic limb of the human body for Pannekoek. It distinguishes humans from other animals, and when it is coupled, in its labour, with artificial tools (and later technologies and machines) it is the driver of progress and history. But this handwork can also connect mind and matter, thought and being, and thereby overcome ideologies arising from such dualisms. This is especially true for our everyday existence in the world as practical beings. But it is also true for the sciences, despite their over-emphasis on the intellectual at the expense of the hand. The last point was already made by Engels, when he observed that the more human society advanced, the more did these advances appear to be the products of the human mind rather than the ‘more modest productions of the working hand’. This lack of appreciation of the hand’s role in the history of the sciences, has consequences for Engels. In particular, when the mundane role of the hand is overshadowed by the glories of the mind we are led to idealism, an ideology that dominates ‘even the most materialistic natural sciences of the Darwinian school’, which is also the main reason that ‘[the Darwinians] do not recognize the part that has been played by labour’.¹⁵ By bringing handwork into the foreground, therefore, we bring back into balance handwork and headwork, according to Engels, so that we might avoid the idealism lurking in our dualist accounts of even the most materialist theories of science.

Pannekoek, too, echoes the same sentiments about the intrusion of ideology into the sciences and their histories. So, for example, he takes to task the early nineteenth century, Scottish anatomist, moralist, and surgeon Charles Bell, and his widely read Bridgewater treatise, *The Hand* (1837). According to Pannekoek, one of the things that Bell fails to appreciate – in a book on the hand, no less – is that touch, by means of the fingers, is not just a passive but also an active ‘energy’. The reason that Bell does not see this, claims Pannekoek, is because ‘the practical life of manual labour is outside of [Bell’s] orbit and his interest’.¹⁶ And again, though Bell sung ‘a hymn of praise to the

13 Pannekoek 1912, 54.

14 Pannekoek 1912, 56, 58; given Pannekoek’s position, the last remains ambiguous.

15 Engels [1876] 1950, 16.

16 Pannekoek [1944] 1953, 14 fn.

human hand', it has remained hollow, because Bell, according to Pannekoek, specialized in 'mental and scientific effort, [such that, if] practical work with tools and the manual labour of the millions producing goods had not been entirely outside his orbit, and if consequently the hand's destination to hold and direct tools had been clear to him, how much deeper a note of world power his hymn of praise would have acquired'.¹⁷ As with Engels on the Darwinists, the irony is that even when a book-length treatise on the hand is imbued with an idealist ideology (e.g. in the case of Bell it is a naturalized religion), it too can underestimate the significance of labour – and even handwork. The implication is clear: we can only ennoble and enrich our sciences, and their histories, with a proper, hands-on appreciation of the labour deeply implicated in handwork. As we shall see below, Pannekoek's astronomical practices exemplified just this kind appreciation.

Pannekoek regarded the sciences themselves as forms of labour, that when understood to include handwork, might eschew lurking ideologies by overcoming, at least in practice, the dualisms of mind and matter, thought and being – dualisms that find their origin in the separations made between physical labour and mental labour, a separation so detrimental to the egalitarian spirit of socialism.¹⁸ Consider the following passage:

[Scientists] deal with nature in their practical activities by acting upon her and making her part of their existence: Through his labour man does not oppose nature as an external or alien world. On the contrary, by the toil of his hands he transforms the external world [...] The object of his thinking is that which he himself produces by his physical and mental activities and which he controls through his brain.¹⁹

I take Pannekoek to be shifting our attention from treating scientists as passive receivers to those who actively toil with their hands so as to make nature a 'part of their existence'. The intimate nature of this labour combats dualisms, precisely because it is rooted in the concreteness of handwork. The

17 Pannekoek [1944] 1953, 17. Recent studies on Sir Charles Bell have shown that as a surgeon he had first-hand experiences of the injuries sustained by factory workers, especially to their hands and fingers; see Capuano 2015, especially chapter 2. But Bell was also very much hands-on when it came to teaching and presenting anatomy by way of models and drawings that he himself made with his own hands; see Berkowitz 2015, especially chapter 2.

18 It is interesting to note that the hand continues to be seen, even to our own day, as a way to overcome dualisms of many different sorts, see for example Radman 2013. Also see the incomplete but influential efforts made by Merleau-Ponty (1968).

19 Pannekoek 1942, 7.

level of labour-intensity involved and the resulting intimacy and concreteness of experience implicated in this account is certainly reminiscent of one of Pannekoek's major philosophical influences: the socialist German tanner and proletarian philosopher, Joseph Dietzgen (1828-1888).

In Dietzgen's *Das Wesen der menschlichen Kopfarbeit* (1869) – a work that, in later editions, included an elaborate introduction by Pannekoek – we encounter a materialist theory of mind grounded in the concreteness of sensuous experience. But unlike the empiricism of the philosophers, this experience is understood as practical, process- and action-oriented; in a word, we might describe it as rooted in handwork. Dietzgen, for example, regards any meaningful, universal statement as having to be grounded in individual objects such that 'we must *handle* definite and concrete objects or phenomena'.²⁰ Even more strikingly, Dietzgen regards any abstract 'science of understanding' that deals with 'all objects' as also being so grounded: 'But all objects which this science may wish to analyse theoretically must first be handled practically. According to their special natures, they must either be *handled in various ways, or carefully inspected, or scrutinized* by intent listening, in short, they must be *thoroughly experienced in some way*'.²¹ A proper understanding of science, therefore, does not disconnect headwork (*Kopfarbeit*) from handwork – Pannekoek would have not just agreed but as we shall soon see this standpoint was a productive source of astronomical knowledge.²²

II

At first blush it would seem that astronomy poses a fatal challenge to handwork in the sciences. Certainly, each science will have its own manner of handling objects, as implied by Dietzgen above. It is easy to see how smelling or tasting might be involved in the handwork associated with chemistry; physics might incorporate listening or touching; while the handwork associated with geology might include rubbing, boring, or crushing. However, unlike chemistry, physics, geology, and the many other sciences besides, astronomy does not have the luxury of having its objects near-to-hand. Its objects are so distant that there is no obvious way we can poke or prod them, twist or turn them, let alone taste, smell, or rub them. Astronomers seem to

²⁰ Dietzgen 1906, 141; emphasis added.

²¹ Dietzgen 1906, 72; emphasis added.

²² See also: Sohn-Rethel 1989.

be forever restricted to the mere optical appearances of astronomical objects (from behind computer screens or optical lenses, mirrors, or atmospheres), separated in space and time from an observer, who stands passive and ready to receive. But whether as a socialist or as an astronomer, this is exactly the view of external objects that Pannekoek rejects.

So how are astronomical objects handled so as to be implicated in handwork? The short answer is that the astronomer's handwork is part-and-parcel of routine acts of recording and representing objects. Since the most ancient times and up to the present, astronomers actively engaged their eyes, minds, and hands. Babylonian astronomers, for instance, literally *chiselled* astronomical records into stone (i.e. cuneiform); while today astronomers use digital technologies to twist and turn three- or four-dimensional objects on their computer screens; in fact, they can even listen to sounds emanating from the universe in order to identify and discover the nature of cosmic objects.²³ When we understand the hand and its tools as a single unit – as Pannekoek suggests we do – we see in these examples cases of astronomical handwork and handling. But in the long history of astronomy, one of the most interesting forms of handwork is handmade drawings, sketches, or even paintings of astronomical objects.²⁴ At least in Pannekoek's own extensive research into the Milky Way, apart from the tables, numerical, and verbal descriptions, one of his primary forms of handwork and handling was drawings and sketches. But before we come to Pannekoek's astronomical handwork, allow me to briefly outline a few examples of how astronomical drawings were made and used as research tools in the nineteenth century, particularly in the case of the nebulae and star clusters, objects thought to have been as elusive as the Milky Way. Doing so will not only cast light on Pannekoek's own labours but will also help us to see how labour so grounded – in the hands and its tools – contributes to astronomical knowledge.

Published drawings of astronomical objects are both records and representations. Once, however, they are printed and the ink has dried on them, it is easy to forget that these were produced over long periods of time, over many nights and days of difficult work. We can therefore see published astronomical drawings, found in many major publications, as either finished products whose surfaces are beheld and treated as mere illustrations; or as the results of long and often toilsome observational procedures that are the highly polished products of many layers of scribbling and sketching, groping and exploring, despair and exhilaration – that is, we can either treat them

23 Kessler 2012; Vertesi 2015; Hadhazy 2014.

24 Even for recent astronomical work image-making is crucial, see Roy 2017

as products or as processes of production.²⁵ In my own work on nineteenth-century drawings of the nebulae, I have opted to explore astronomical images from the perspective of processes or picture-making rather than as pictures.²⁶ It is from the perspective of process that I believe we can best, for our present purposes, explore the astronomer's labour of handwork.

When we turn to the laborious processes of picture-making, we find diverse preliminary, preparatory, tentative sketches made by astronomers, which reside as records in their private observational notebooks that were used to build up a final image-product for publication. These provisional images acted as mutable tools to see better or more with, to expand what is possible in the object or to limit how the object is seen, or simply to direct us to look in particular places in our next set of observations. These paper-tools were especially effective for extremely faint and notoriously difficult observational objects like the nebulae, star clusters, or the Milky Way. Image-making techniques like drawing with paper and pencil were used as observational tools, and it is for this reason that I have elsewhere called such a practice, 'observing by hand'.

Such observational tools as stylus and paper, moreover, could be refined and adjusted not just by the pressure applied to the pencil, chalk or ink, or the type and texture of paper selected, but also by means of switching between colours, shades, and positive or negative images of the object. Though there are many examples of this practice found in the observing books of nebular observers of the nineteenth-century, one of the best comes from the labours of George P. Bond (1825-1865) at the Harvard Observatory. Using multiple media, Bond dedicated nearly six, very intensive years drawing the nebula in Orion (M42) (Figure 12.1). In 1858, he began by plotting out 262 stars on paper, which provided the support for the entry of the faint nebulosity. The latter was entered after the area surrounding the nebula was divided into four charts on dark ground so that the nebulosity could be traced in, using white chalk and watercolours. Once these parts were entered, the four distinct charts were then recombined and checked as a whole against the object as seen through the telescope, only to be corrected accordingly. In the third year of this procedure, he continued to draw the brighter parts of the nebulae using white chalk on dark paper, so that he could adjust for the different intensities of light in relation to the darkness. But at the same time, almost as a check, Bond drew the same areas in the negative, where

25 For the classic treatment of astronomical images as mere illustrations to be beheld by perception, see Sheehan 1988.

26 For a much more detailed account of what follows, see Nasim 2013.

Figure 12.1 Published drawing of the nebula in Orion as drawn by George P. Bond



Source: William C. Bond, George Phillips Bond, and Joseph Winlock, *Results of Observations*, *Annals of the Astronomical Observatory of Harvard College* 8 (Cambridge, MA: John Wilson and Son, 1876), courtesy of Linda Hall Library of Science, Engineering & Technology

the light parts were drawn in dark media against a white background. It was by means of this back-and-forth between media that Bond discovered the supposed spiral character of M42.²⁷

Besides the novel features of the nebula that Bond revealed to himself (and eventually to others as well), what stands out is his dedication and handwork in producing an image of it over a period of six years, despite his failing health. Since 1858, Bond had suffered from tuberculosis and it seems that his ‘monomania obsession’ to draw the nebula by hand only hastened his untimely death. A month before he died in 1865, at the age of 39, Bond wrote to his assistant:

My disease makes progress, and leaves me little hope of putting the materials of my work on Orion – to which I had devoted so much labour – into condition such that another could prepare them for the press. In truth, I am becoming resigned to the idea that most of it is destined to oblivion.²⁸

²⁷ Bond 1861.

²⁸ Letter from Bond to Asaph Hall, January 7, 1865; quoted in Sheehan and Conselice 2016, 97.

It was two years after his death that the full account and the final resulting drawing of M42 was engraved in steel and published.²⁹ The labour that it cost Bond was widely noted, and as late as 1882, Edward S. Holden, director of the Washburn Observatory (and soon to be director of the Lick Observatory) used Bond's published image of M42 as a frontispiece to a whole book dedicated to hundreds of drawings of this nebula, declaring it to be 'the most satisfactory representation of any celestial object which has yet been produced'.³⁰

The years that Bond spent, ceaselessly experimenting with media in order to make out the subtleties of the notoriously intricate nebula in Orion, was time and labour essential in coming to know the unfamiliar. Bond's example shows how the hand and eye can work together through multiple materials and media. But there are also examples of how the hand and eye can be further supplemented in observing and drawing astronomical objects by particular conceptions of the mind. At Yale College, in the summer of 1839, E.P. Mason and H. Smith built themselves a telescope for the express purpose of observing and drawing nebulae. Essential to the observational procedure used to compose the drawings, were chains of triangles and isolines laid down on paper – one was used to survey and plot the stars trigonometrically onto paper, and the other to aid in the entry of various gradations of light and dark involved in the nebulae. Each of these artificial aids were referred to as 'conceptions' that worked together to build up, over time and many observations, a unified picture of a nebula.³¹ Indeed, the configurations evidenced in Mason's practice between the hand, eye, and mind echo one of Pannekoek's fundamental claims: 'Since the tool stands between man and outside objects, thought must arise between the impression and the performance [...] This material circuit causes the mental circuit; the thoughts leading to a certain act are the results of the tools necessary for the performance of the act.'³²

But it is the example of another nineteenth-century observer of the nebulae who, independently of Mason, took a similarly conceptual approach to another level and who's practice nicely exemplifies Pannekoek's claim, quoted above. This was none other than John F.W. Herschel, who, while situated with his family and his twenty-foot reflecting telescope at the Cape of Good Hope, spent four years (1834-1838) drawing and

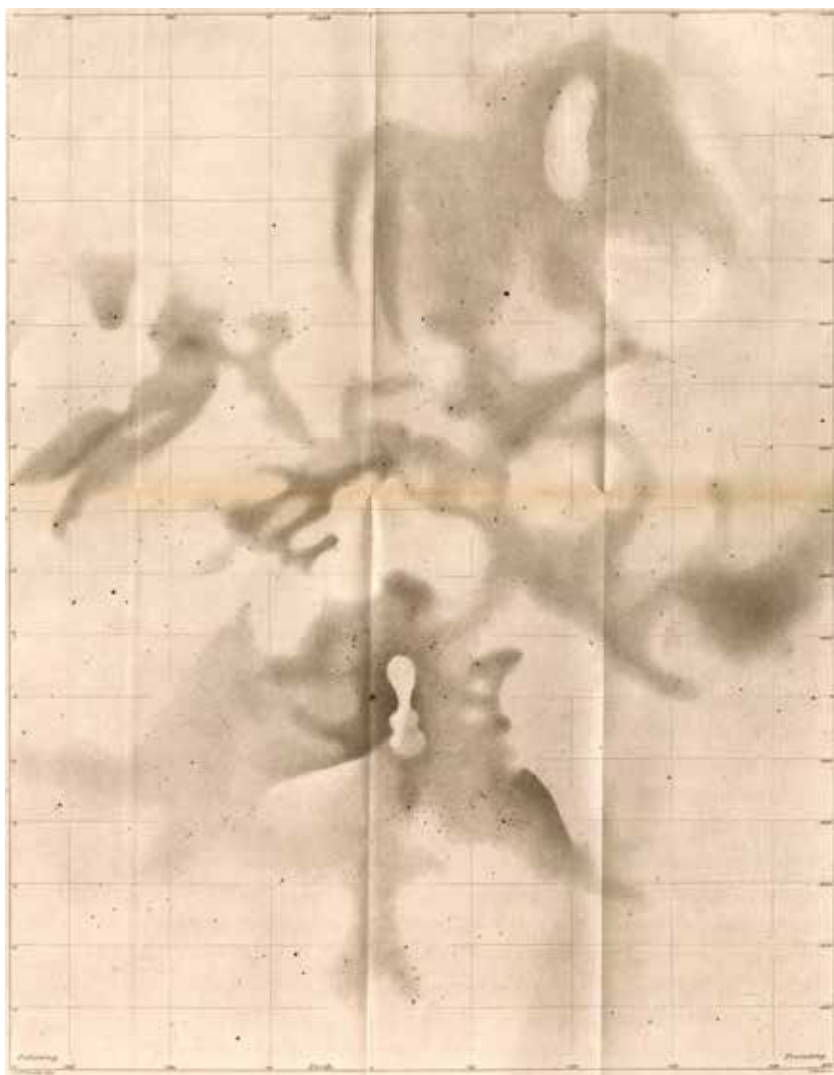
29 Bond 1867.

30 Holden 1882, 82.

31 Mason 1841. For further detail, see Nasim 2013, 126-137.

32 Pannekoek 1912, 46.

Figure 12.2 Printed descriptive map of η Argus, published in John Herschel's *Cape Results*



Source: John F.W. Herschel, *Results of Astronomical Observations Made during the Years 1834, 5, 6, 7, 8, at the Cape of Good Hope; Being the Completion of a Telescopic Survey of the Whole Surface of the Visible Heavens, Commenced in 1825* (London: Smith, Elder & Co., 1847)

cataloguing the nebulae and clusters of the southern hemisphere. Even after he returned home to England, he continued to catalogue, calculate, and draw for at least another six years, when in 1847 he finally published the results that included a number of splendid prints of the nebulae,

clusters, and even the Milky Way.³³ From just the printed image-surfaces of these published pictures one cannot surmise all that went into their production (Figure 12.2). Turning to Herschel's backstage work, however, one is struck by the use of pencilled in dots and lines that form chains of triangles and grids. These triangles and grids are the 'working skeletons' that were employed to triangulate the approximate, relative positions of the stars and nebulous material. Each one contains layers of handwork. In some cases, as many as 23 successive 'working skeletons', each on a separate piece of paper, were used in the production of just one final image of a nebula. The skeletons provide consistency, regularity, measure, and scale to his pictures of deep-sky objects that are notoriously hard to see and measure. But above all, they provide a way to coordinate what the eye sees and what the hand enters onto paper, allowing Herschel to scrutinize each and every single part of a nebula in a systematic and highly attentive manner. I have also argued elsewhere that these conceptual tools on paper corresponded to Herschel's own understanding of the specific mental processes employed in the construction of external objects. But for our purposes, the handwork implicated in this observational procedure should not be underestimated. When writing about all the work involved in picturing just one nebula, Herschel shifts to a personal, intimate style in order to explain his labour:

The accurate representation of this nebula with its included stars has proved a work of very great difficulty and labour [...] To say that I have spent several months in the delineation of the nebula, the micrometrical measurement of the co-ordinates of the skeleton stars, the filling in, mapping down, and reading off the skeletons when prepared, the subsequent reduction and digestion into a catalogue, of the stars so determined, and the execution, final revision, and correction of the drawing and engraving, would I am sure, be no exaggeration. Frequently, while working at the telescope on these skeletons, a sensation of despair would arise of ever being able to transfer to paper, with even tolerable correctness, their endless details.³⁴

The level of intensity and intimacy of handwork, exhibited in Herschel's observational procedures, was essential, however, to the production of accurate published images that could then go on to be used by scientists. In

33 Herschel 1847.

34 Herschel 1847, 37.

addition to this, the disciplined handwork behind each of Herschel's drawings was necessary in order to safeguard the results from the detrimental influences of the intrusion of the self.³⁵

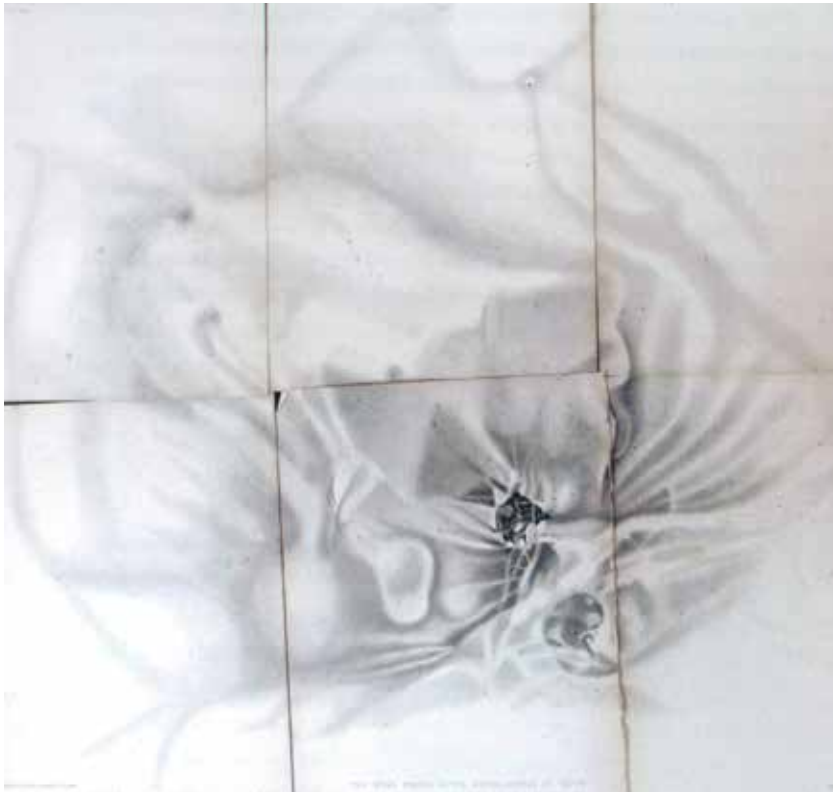
The handwork required in the production of these visual representations did not always rely on one individual observer but could extend to include the hands and tools of many. Employing a very similar set of working skeletons as Herschel, William Parsons (the third Earl of Rosse (1800-1867)) and his assistants, which included his son Lawrence Parsons (Lord Oxmantown, 1840-1908), Robert S. Ball (the future Astronomer Royal for Ireland, 1840-1913), and the artist Samuel Hunter, all contributed to the production of a celebrated drawing of the nebula in Orion (M42), published in 1868 (Figure 12.3). The groundwork for the elaborate drawing was laid down using micro-metrical measurements of 150 stars in and around the nebula, taken by Otto Struve, the director of the Pulkovo Observatory, near St Petersburg. Back in Ireland, Lord Rosse's team of observers used this data to create the paper-ground for the construction of a grid that would be used to then plot in other stars not included in Struve's catalogue. With the paper so prepared, the observers entered, over many nights, the minutia and complexity of this nebulous object in a way that was governed by the stars and the lines of the grid. Rosse's 'Skeleton Map' of M42 coordinated *seven years of work*, which included multiple entries from a number of hands, and different telescopes. Besides the detailed drawing of the nebula, which was engraved and printed for the publication, a topographical map of the nebula was also included, one that only showed the outlines of the nebula and identified by labels all the main stars and regions to be found therein. The painstaking labour of this handwork should not be underestimated. After having made 74 observations between 1860-1864 for the purposes of drawing the nebula in excruciating detail, Samuel Hunter, who did the large bulk of the work, reportedly became so ill that he had to leave the Earl's employ.³⁶ But in introducing the publication that included the drawing and map of M42, it is precisely this exhausting level of handwork that Lawrence Parson highlights, especially as a reason to regard the new figure of the nebula as accurate, efficacious, and true.³⁷

35 See Nasim 2013, 137-167.

36 Besides the work for M42, Hunter was also observing the moon, collating the notebooks, and continuing with the observations for the survey of the nebulae in general. See Nasim 2013, chapter 1.

37 Oxmantown 1868.

Figure 12.3 Drawing of the nebula in Orion by Samuel Hunter based on collaborative efforts of Robert Ball, William Parsons, and Lawrence Parsons



Source: The Rosse Papers, Birr Scientific and Heritage Foundations, courtesy of the Earl of Rosse

We can provide other examples of how handwork was implicated in astronomical knowledge. But doing so would only belabour the point that I hope has now been sufficiently made, that the act of drawing was a productive way for astronomers to come to know distant objects in ways that were intimate, intense, and laborious. That through the interactions of the eye, mind, and hand, observers made astronomical objects a part of their personal existence. That these systematic interactions were so demanding, only meant that they led not just to despair or illness but to visual representations that were so disciplined so as to show what was really there – or so it was thought. Indeed, that they expended so much energy and life into these drawings only goes to show the immense value that they placed on the products and the processes. And all this thanks to the sheer amount of time spent using one's hands in relation to reams of paper and notebooks, telescope, and

styli (whether pencil, ink and pen, or brush), over and over again. According to Pannekoek, then, this is not just how human beings first emerged and came to dominate nature. It is also how they, even in their more advanced sciences, come to know the world:

A new and powerful influence emanates from the handling of tools to the organs of perception and consciousness, and thereby to mental life. It supplies a new experience of the exterior world. The delicate sense of touch vested in the fingers comes into action when gripping and guiding the tool which is used to operate on the outside world by some such as beating, pressing, rubbing, and boring [and we might add drawing] [...] The exterior world reacts, as its resistance.³⁸

I take the examples provided above, as instantiating these claims. Let us now turn to Pannekoek's own representational practices to find something similar.

III

Over the span of his long astronomical career, Pannekoek made many sorts of drawings of the Milky Way, an object that occupied his hands for nearly sixty years. His first systematic attempts at observing the Milky Way date back as early as the years 1889 to 1890.³⁹ During this period, the young Pannekoek already preferred to depict the Milky Way using a series of isophotic lines – lines representing numerically the same level of brightness – in order to describe the different gradations of light on paper blackened so that the stars and lines could appear white (by using white lead). This media was selected primarily because it made it easier to draw in the dark, once the naked eyes were night-adopted and directly perceiving the Milky Way. Afterwards, Pannekoek advises that these charts be 'copied at home' upon another set of charts made on white paper and constructed on the basis of Albert Marth's catalogue of the main stars in the neighbourhood of the Milky Way.⁴⁰ From all the information gained, a number of drawings of three different regions of the Milky Way were made between 1890-1892. It was based on these experiences that Pannekoek published a note in 1897 recommending astronomers to use 'new charts for inserting the Milky

38 Pannekoek [1944] 1953, 61.

39 I take this timeline chiefly from the introduction to Pannekoek 1920.

40 Pannekoek 1898, 527.

Way'. These were essentially the same pre-prepared charts that he had previously used for his own observations and drawings, and he suggested that copies, as lithographs, would be made available to other observers around the world, who were also drawing the Milky Way. Quite early in his astronomical career, therefore, Pannekoek opted to pursue a visual strategy that was defined by handwork.

Pannekoek's isophotic maps of the Milky Way do not show the phenomenon as it is seen in the sky, however. For this, much more naturalistic and detailed drawings had to be made. The observations for these were begun in 1893 but had come to an end in 1899, due to Pannekoek's routine duties at the Leiden observatory, which were, he writes, 'too exhausting for me'. Between 1910-1913, Pannekoek resumed his observations and found that he could compose 'a total picture of the Milky Way'.⁴¹ The total picture was divided into three different regions of the Milky Way. What served as the basis for these unified compositions were not just years of notes, charts, stars, drawings – both naturalistic and schematic – but also 128 select points whose specific levels of brightness were estimated by the eye and given a numerical value that could be used as standard for the determination of light intensities throughout the rest of the Milky Way. It was finally in 1920 that Pannekoek published the results of the above observations. In it, Pannekoek presented naturalistic drawings of three regions of the Milky Way, all printed in the positive (Figure 12.4). The same regions were also figured in three detailed isophotal maps (Figure 12.5). But the most notable figures were what he called 'the mean subjective images', which schematically combined his own drawings with those of at least three other major observers of the Milky Way (Figure 12.6). All in all, these different visual approaches, or as Pannekoek refers to them, 'lines of research', were intended to complement one another: He explained:

When on a star chart we draw the lines of equal brightness by shading the region between them with increasing deepness, then blending these shades into one another at their boundary lines, we have a picture with good distribution of brightness, but showing only the more general details, though it gives the general appearance very well. Upon this background, we can draw the minutest peculiarities, taken from the results of the studies [...] we have a picture that contains all that the observer has been able to see, and which still shows the brightness of the different parts in a very exact proportion.⁴²

41 Pannekoek 1920, 2.

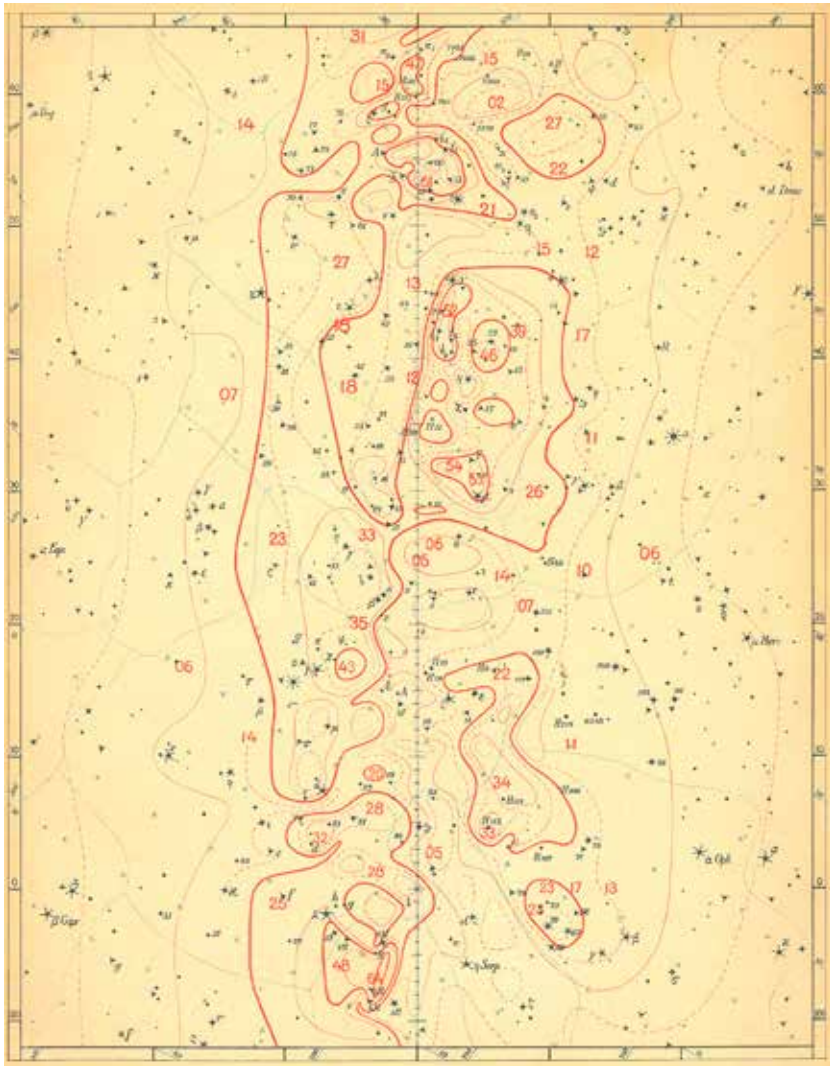
42 Pannekoek 1898, 528.

Figure 12.4 Naturalistic drawing of a region of the northern Milky Way by Pannekoek



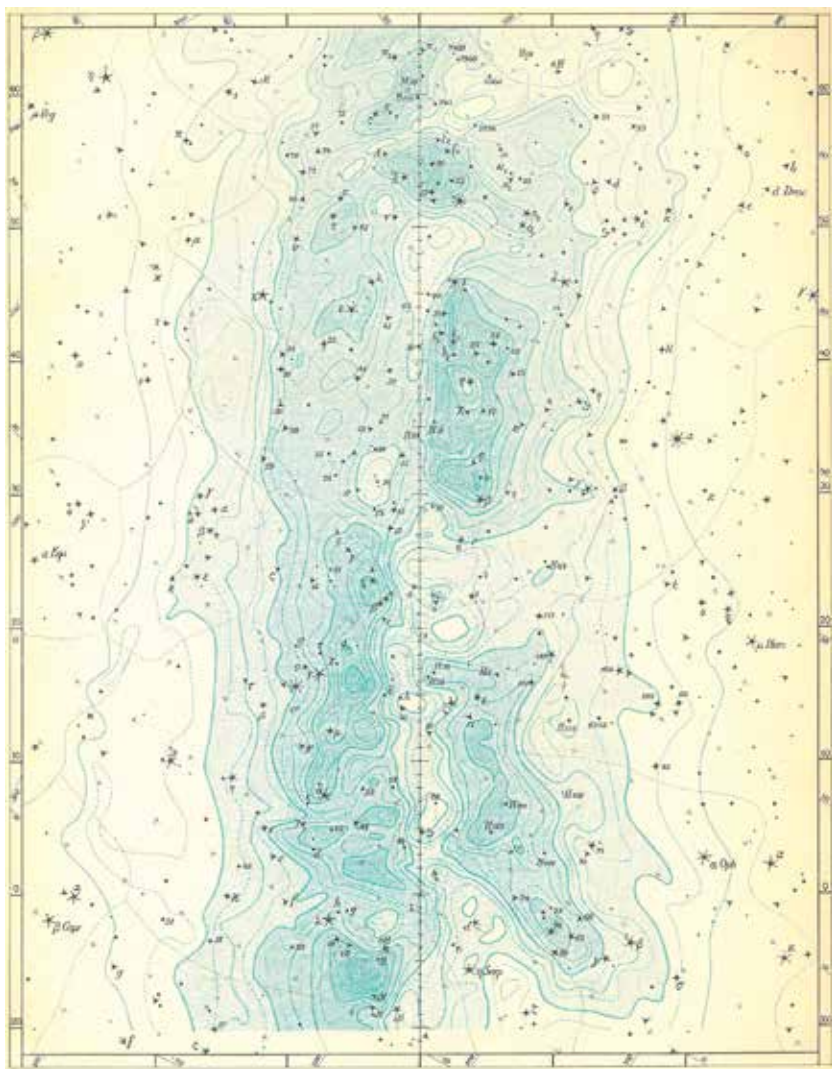
Source: Anton Pannekoek, *Die nördliche Milchstrasse*, *Annalen van de Sterrewacht te Leiden* 11:3 (Haarlem: Joh. Enschedé en Zonen, 1920)

Figure 12.5 Isophotal map by Pannekoek of the same region of the northern Milky Way based on his own observations



Source: Anton Pannekoek, *Die nördliche Milchstrasse*, *Annalen van de Sterrewacht te Leiden* 11:3 (Haarlem: Joh. Enschedé en Zonen, 1920)

Figure 12.6 The mean subjective image of the northern Milky Way, which combined the drawings of Pannekoek with those of others



Source: Anton Pannekoek, *Die nördliche Milchstrasse*, *Annalen van de Sterrewacht te Leiden* 11:3 (Haarlem: Joh. Enschedé en Zonen, 1920)

Figure 12.7 Naturalistic drawing of a region of the southern Milky Way, published in negative

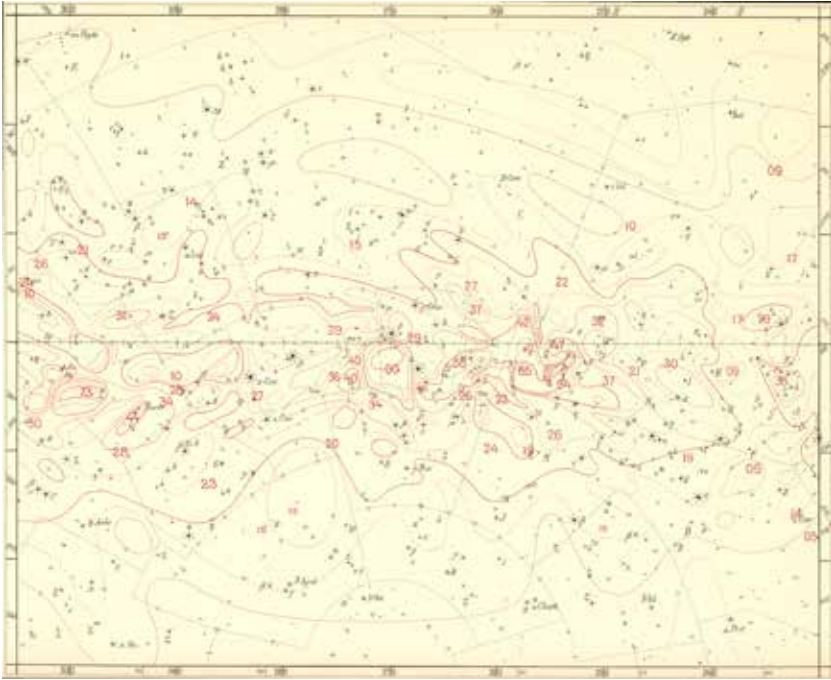


Source: Anton Pannekoek, *Die südliche Milchstrasse*, *Annalen van de Bosscha Sterrenwacht* 2:1 (Amsterdam: De Bussy, 1928), plate 2

The active alternation between different media and techniques of representing – naturalistic and schematic – is certainly indicative of drawings used not just for presentation but as tools for observing. Again, we have not just pictures but means to observe more attentively and differently with. The artefacts of Pannekoek’s handwork also speak to the intensity of labour, time and handicraft implicated in his observational procedures. Given the significance of handwork for his procedures, it is little wonder, then, that the next time Pannekoek published drawings of the Milky Way, as seen from the southern hemisphere, he remained unsatisfied with them, because they were produced in a relatively short period of time.⁴³ These were observations made within just six months, between 1925-1926 at the Bosscha observatory in Lembang, Indonesia. Thanks to bad weather and a short stay, Pannekoek could not properly engage in the same amount of labour-intensive scrutiny of the Milky Way as he

43 See Pannekoek 1928.

Figure 12.8 The corresponding isophotic map of the same region of the southern Milky Way



Source: Anton Pannekoek, *Die südliche Milchstrasse*, *Annalen van de Bosscha Sterrenwacht* 2:1 (Amsterdam: De Bussy, 1928), plate 5

had done previously. Though three naturalistic figures (all printed, this time, in the negative; Figure 12.7) and three corresponding isophotic maps (Figure 12.8) were published for three regions of the southern Milky Way, these, for Pannekoek, remained incomplete precisely because they lacked a sufficient amount of labour. One might fairly ask at this juncture: Why did Pannekoek not just use photography? After all, Pannekoek already had some experience working with photography; and that by this time there were already a handful of successful and exemplary photographs taken of the Milky Way. In order to approach an answer to this question, we need to step back a bit and reconsider the use of photography in the sciences from a wider angle, one that will put us in a position to see dualism lurking around the corner; dualisms that Pannekoek wished, due to his socialist orientation, to avoid.

IV

It might appear that we have moved very far from socialism. But let us recall that the human hand and its tools were not just central to Pannekoek's view of science but also to his socialism. Indeed, the hand and its tools have been emblematic of early socialist theories, especially as they arose in reaction to the rise of automatic 'iron fingers' powered by steam engines. The common rhetoric in defence of these machines should be familiar enough: they save time and human labour; and they supplant handwork so that more time can be shifted to more privileged kinds of work, like headwork. Intriguingly but unsurprisingly, a similar rhetoric can be found in the rise of astrophotography. So, for example, in contrast to the tireless eyes of photography, the astronomer and popularizer Robert Proctor sardonically refers to those who made drawings of the nebulae as 'our *laborious telescopists* [who] wait and watch until at least the true shapes of these mysterious mist masses had been determined. But with long looking comes only more confused vision'.⁴⁴ Or take the case of Edward S. Holden, who describes photography as the 'servant' of astronomy, which does not tire in its faithful and 'automatic register'. He continues: 'Another important advantage of the new methods [of photography] is that they do not require highly skilled observers [...] The skill of the astronomer is reserved for real difficulties, and the merely laborious work can be done in duplicate, if necessary, by younger men'.⁴⁵ By 'real difficulties' the famously heavy-handed director of Lick Observatory was presumably referring to the headwork of the astronomer, rather than the deskilled labour of the hand.

Consider once again the case of George P. Bond, who, before starting on the laborious project of drawing the nebula in Orion, was among the first to employ photography to capture the stars. In contrast to what we have seen above, Bond applauds the relative ease of photography, especially as a labour-saving mechanism: 'On a fine night', he writes, 'the amount of work which can be accomplished, with entire exemption from the trouble, vexation and fatigue that seldom fail to attend upon ordinary observations, is astonishing. The plates, once secured, can be laid by for future study by daylight and at leisure. The record is there, with no room for doubt or mistake as to its fidelity'.⁴⁶ But despite these high praises, Bond was soon to quit his experiments with photography, due to a number of challenges, including

44 Proctor 1883, 447; emphasis added.

45 Holden 1886, 467, 468.

46 Bond 1890, 301.

the prohibitive costs involved in the venture. What does continue, however, are the tropes of leisure and fidelity, closely associated with photography well into the twentieth century.

Perhaps the most striking are the remarks of Sir Robert S. Ball, who, as a young man, was engaged with Lord Rosse's grand project of drawing the nebula in Orion. Many years after his work with the Earl, the Astronomer Royal for Ireland recollected that it was

with infinite patience, Lord Rosse devoted years to making a drawing of the Great Nebula [in Orion]. Those were not the days of astronomical photography [...] It is an exquisite piece of work. It was repeatedly compared with the actual object in the heavens, and corrected or altered until accuracy was attained. In some respects we may say it is unique. Never before was so much pains bestowed on the drawing of a celestial object, and never again will equal pains be devoted to the same purpose. In an hour or two the photographic plate will now record much more than the most accomplished astronomer can observe, even though his repeated observations cover a period of several years.⁴⁷

The same rhetoric can be found in the twentieth century, where, even in Pannekoek's writings we find claims such as: '[T]he first photographs of the sun and the moon showed, in short exposures, an abundance of detail that would have demanded hours and months of observing in direct drawing and mapping'.⁴⁸ These fine photographic details, finally, could be examined at one's leisure during the day and in the comfort of one's own office. Astrophotography radically challenged the labour practices of the 'old astronomy' and introduced brand-new labour relations.⁴⁹ More importantly, however, photography's purportedly hands-free labour, and time-reducing character, seem to directly mitigate against our notion of handwork in astronomy – a notion that operates on the basis of the intensity of long and trying labour of the astronomer's hands and tools. And just as in the case of ideologically governed rhetoric surrounding the steam engine, here too we have an ideologically driven rhetoric, one wherein astrophotography is more conducive to headwork than handwork. In fact, things have been turned on their head: while the painstaking labour of the previous generation's handwork (in drawing nebulae, for instance)

47 Ball 1915, 69.

48 Pannekoek 1961, 336; see also 373.

49 Clerke 1888; see also Nasim 2016.

was seen as a guarantor of representational reliability; now, at the end of the nineteenth century, the same painstaking handwork was seen as mitigating against the reliability of what was produced, especially in light of photography. Photography, therefore, seems to have been pitted against the handwork manifest in drawings – we have, in other words, another series of hazardous dualisms. Given this situation, it is of some significance to notice Pannekoek's own reaction to these dualisms within his own astronomical practice: true to form they are made to merge by means of not less but more handwork.

V

Allow me to conclude by addressing this challenge, for doing so will help to further reinforce the overall significance of handwork for Pannekoek's socialism and astronomy. There are a number of related ways one can react: One can simply observe, to begin with, how the rhetoric of photography conflicts with the vast number of manuals dedicated to photography, which explicitly included the labour of handwork into the very processes of photography. Photography, in other words, is not wanting in hands and handling.⁵⁰ Another is to simply point out the fact that Pannekoek maintains an important space for the visual in contrast to photographic work in observational astronomy. After contrasting, for instance, the photographic from visual atlases of the moon, Pannekoek argues, as late as 1951, that given certain limitations of lunar photography, 'visual work should not be abandoned'.⁵¹ And in the case of the Milky Way, especially given photography's failure to adequately show the overall brightness and milkiness of the Milky Way, the images produced by visual means remains absolutely crucial.

This leads me to the final point. Although Pannekoek seems to divide the visual and photographic, his characteristic aversion to dualism and his commitment to handwork bring these two kinds of images into a complementary relationship within his own practice. One of the most distinctive things about Pannekoek's two most important publications on the photographic photometry of the Milky Way is just how many hand-drawn, schematic

⁵⁰ This is so also for astrophotography, see, for instance, Scheiner 1897; Abney 1893. For more on hands and photography in astronomy, see Nasim 2018. For more on labour and photography generally, see Edwards 2006.

⁵¹ Pannekoek 1961, 374.

maps there are as opposed to photographs – and this in a book based on photographic methods. In the first publication on the northern Milky Way (1933), there are just eight photographs of stars printed on two plates (Figure 12.9), compared to 35 separate plates for schematic translations (by hand) of the photographs used (Figure 12.10), and another eight entire plates showing the isophotal maps derived (again by hand) from these photographs (Figure 12.11).⁵² The second major publication is dedicated to extending the same methods to the southern Milky Way (1949).⁵³ It contains four photographs of the stars on one plate, two plates with naturalistic drawings, and fifteen plates of isophotal maps. The quantitative and qualitative information visualized by means of multiple schematic maps, all made by hand, are derived from photographs showing the stars of the Milky Way as no human eye can see them (Figure 12.12). From these extrafocal photographs of the stars, Pannekoek maps out a number of quantities of light intensity, magnitudes, and gradations by hand and eye, all in gruelling detail. And even though all the photographic plates used for these publications – spanning a period of nearly thirty years – come from a variety of cameras and optics, telescopes and astronomers, climates and geographies, they are harmonized by means of a battery of reductions and projections in order that the information be depicted in a series of coherent hand-drawn maps. But it is not just schematic maps that are derived; Pannekoek goes as far as to actually translate the series of extrafocal photographs of stars into naturalistic, shaded drawings of the Milky Way (Figure 12.13). Again, we have a variety of media made to supplement and complement one another. Most importantly, however, is the fact that even in the case of photography, Pannekoek grounds the work back into laborious handwork.

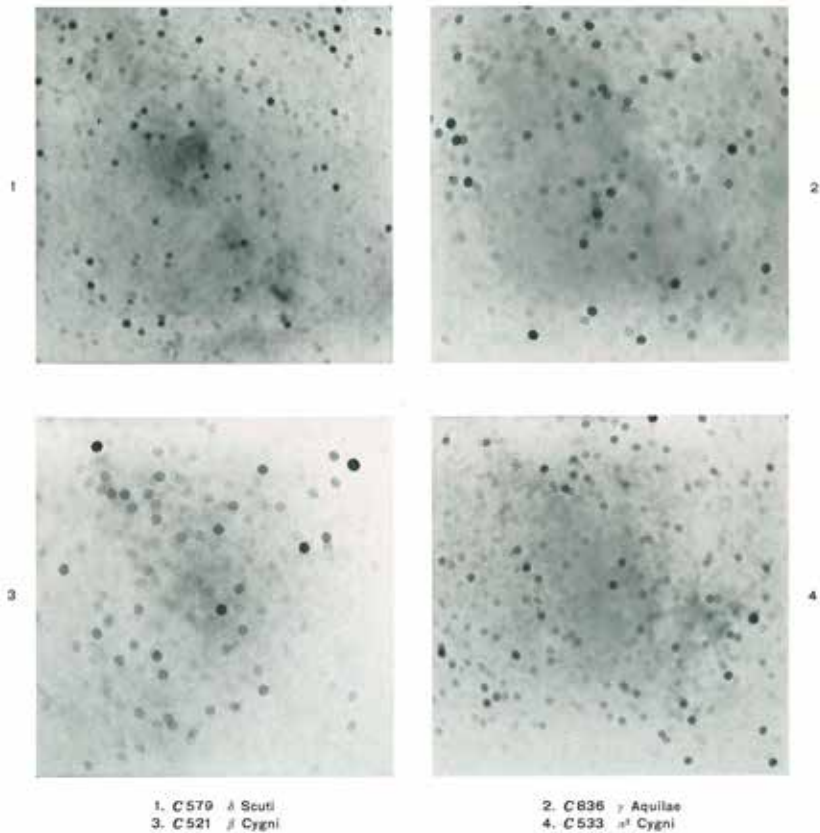
Even behind Pannekoek's photographic labours, therefore, there is a preference for handwork, reflecting a phenomenology that hearkens back to Dietzgen's epistemically productive and intimate handling of scientific objects, which afford a level of scrutiny otherwise not available by other, more automatic means. It is through patient and painstaking handwork that the objects of science are brought into the very fibres of the scientist's existence. It is for this reason that even photographs are anchored into handwork; or as Pannekoek puts it in a pithy but revealing statement: 'Photography, with all its documentary value [...] misses [however] the direct contact with the happenings of every moment'.⁵⁴ In

52 Pannekoek 1933.

53 Pannekoek and Koelbloed 1949.

54 Pannekoek 1961, 416.

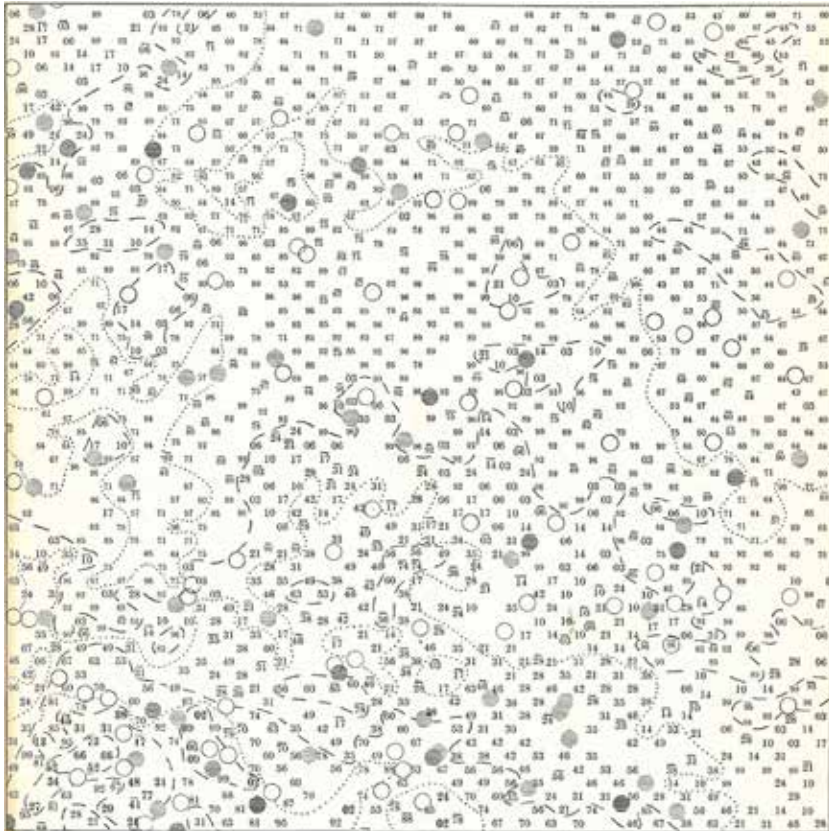
Figure 12.9 Published reproductions of the northern Milky Way photographs



Source: Anton Pannekoek, *Photographische Photometrie der nördlichen Milchstrasse*, Publications of the Astronomical Institute of the University of Amsterdam 3 (Amsterdam: Stadsdrukkerij, 1933)

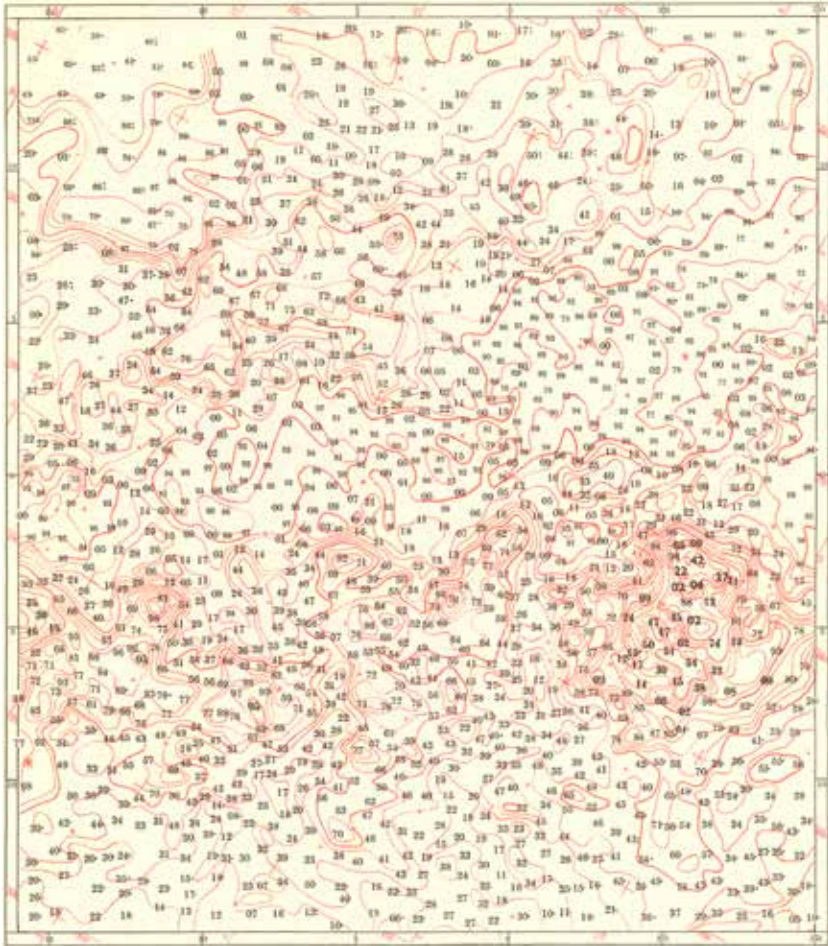
terms of handwork, that is to say, there is a surplus of experiences born of laborious and time-consuming handling by means of the hands and its tools – a surplus that photography seems to lack when employed by itself. Whether it is Marxism or Darwinism, thought or being, drawing or photography, these dualisms can, according to both Pannekoek-the-astronomer and Pannekoek-the-socialist, be superseded and, indeed, be made complimentary by human hands and tools. Handwork is crucial to both sides of Pannekoek's oeuvre.

Figure 12.10 A plate with schematic translations of one of the photographs used



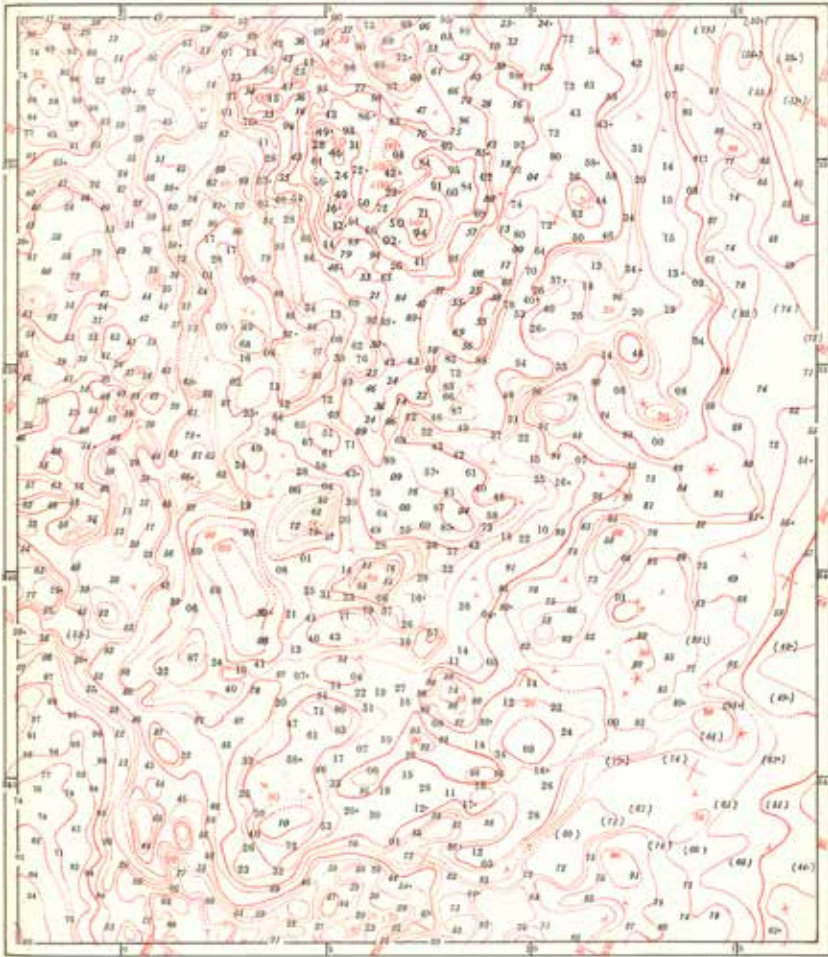
Source: Anton Pannekoek, *Photographische Photometrie der nördlichen Milchstrasse*, Publications of the Astronomical Institute of the University of Amsterdam 3 (Amsterdam: Stadsdrukkerij, 1933)

Figure 12.11 Isophotic map that is derived from the schematic translations of the Milky Way photographs



Source: Anton Pannekoek, *Photographische Photometrie der nördlichen Milchstrasse*, Publications of the Astronomical Institute of the University of Amsterdam 3 (Amsterdam: Stadsdrukkerij, 1933)

Figure 12.12 Isophotic map derived from photographs of the southern Milky Way



Source: Anton Pannekoek and David Koelbloed, *Photographic Photometry of the Southern Milky Way*, Publications of the Astronomical Institute of the University of Amsterdam 9 (Amsterdam: Stadsdrukkerij, 1949)

Figure 12.13 Naturalistic drawing of the southern Milky Way derived from photographs of the southern Milky Way



Source: Anton Pannekoek and David Koelbloed, *Photographic Photometry of the Southern Milky Way*, Publications of the Astronomical Institute of the University of Amsterdam 9 (Amsterdam: Stadsdrukkerij, 1949)

Bibliography

- Abney, William de Wiveleslie. 1893. *A Treatise on Photography*. 9th edition. London: Longmans, Green & Co.
- Ashworth, William J. 1994. 'The Calculating Eye: Baily, Herschel, Babbage and the Business of Astronomy'. *British Journal for the History of Science* 27(4): 409-441.
- Ball, Robert. 1915. *Reminiscences and Letters of Sir Robert Ball*. Ed. by W. Valentine Ball. Boston: Little, Brown & Co.
- Berkowitz, Carin. 2015. *Charles Bell and the Anatomy of Reform*. Chicago, IL: University of Chicago Press.
- Bond, George P. 1861. 'On the Spiral Character of the Great Nebula in Orion'. *Monthly Notices of the Royal Astronomical Society* 21(7): 203-207.
- . 1867. *Observations upon the Great Nebula of Orion*. Ed. by Truman H. Safford. *Annals of the Astronomical Observatory of Harvard College* 5. Cambridge, MA: Riverside Press.
- . 1890. 'The Future of Stellar Photography: Extract from a Letter Written in 1857 to Wm. Mitchell by G.P. Bond'. *Publications of the Astronomical Society of the Pacific* 2(11): 300-302.
- Capuano, Peter J. 2015. *Changing Hands: Industry, Evolution, and the Reconfiguration of the Victorian Body*. Ann Arbor, MI: University of Michigan Press.
- Clerke, Agnes Mary. 1888. 'Astronomical Photography'. *The Sidereal Messenger* 7(46-47): 138-153, 181-191.
- Dietzgen, Joseph. 1906. *The Positive Outcome of Philosophy: The Nature of Human Brain Work; Letters on Logic*. Chicago, IL: Charles H. Kerr & Co.
- Edwards, Steve. 2006. *The Making of English Photography: Allegories*. University Park, PA: Pennsylvania State University Press.
- Engels, Friedrich. (1876) 1950. *The Part Played by Labor in the Transition from Ape to Man*. New York: International Publishers.
- Hadhazy, Adam. 2014. 'Heavenly Sounds: Hearing Astronomical Data Can Lead to Scientific Insights'. *Scientific American*. <https://www.scientificamerican.com/article/heavenly-sounds-hearing-astronomical-data-can-lead-to-scientific-insights/> (accessed 23 January 2017).
- Herschel, John F.W. 1847. *Results of Astronomical Observations Made during the Years 1834, 5, 6, 7, 8, at the Cape of Good Hope; Being the Completion of a Telescopic Survey of the Whole Surface of the Visible Heavens, Commenced in 1825*. London: Smith, Elder & Co.
- Holden, Edward S. 1882. *Monograph of the Central Parts of the Nebula of Orion*. Washington, DC: Government Printing Office.
- . 1886. 'Photography the Servant of Astronomy'. *Overland Monthly* 8(47): 459-470.
- Kessler, Elizabeth A. 2012. *Picturing the Cosmos: Hubble Space Telescope Images and the Astronomical Sublime*. Minneapolis, MN: University of Minnesota Press.

- Mason, E.P. 1841. 'Observations on Nebulae with a Fourteen Feet Reflector, Made by H.L. Smith and E.P. Mason, during the Year 1839'. *Transactions of the American Philosophical Society* 7: 165-213.
- McGinn, Colin. 2015. *Prehension: The Hand and the Emergence of Humanity*. Cambridge, MA: MIT Press.
- Merleau-Ponty, Maurice. 1968. *The Visible and the Invisible: Followed by Working Notes*. Evanston, IL: Northwestern University Press.
- Napier, John. 1970. *The Roots of Mankind*. Washington, DC: Smithsonian Institution Press.
- . 1980. *Hands*. Princeton, NJ: Princeton University Press.
- Nasim, Omar W. 2013. *Observing by Hand: Sketching the Nebulae in the Nineteenth Century*. Chicago, IL: University of Chicago Press.
- . 2016. 'Astrofotografie und John Herschels "Skelette"'. In *Zeigen und/oder Beweisen? Die Fotografie als Kulturtechnik und Medium des Wissens.*, ed. by Herta Wolf. Berlin: De Gruyter, 157-178.
- . 2018. 'James Nasmyth on the the Moon: Or on Becoming a Lunar Being without the Lunacy'. In *Selene's Two Faces: From 17th Century Drawings to Spacecraft Imaging*, ed. by Carmen Pérez González. Leiden: Brill, 147-187.
- Oxmantown, Lord [Lawrence Parsons]. 1868. 'An Account of the Observations on the Great Nebula in Orion, Made at Birr Castle, with the 3-Foot and 6-Foot Telescopes, between 1848 and 1867. with a Drawing of the Nebula'. *Philosophical Transactions of the Royal Society of London* 158: 57-73.
- Pannekoek, Anton. 1898. 'III. On the Best Method of Observing the Milky Way'. *Popular Astronomy* 5(50): 524-528.
- . 1912. *Marxism and Darwinism*. Trans. by Nathan Weiser. Chicago, IL: Charles H. Kerr & Co.
- . 1920. *Die Nördliche Milchstrasse*. *Annalen van de Sterrewacht te Leiden*, 11:3. Haarlem: Joh. Enschedé en Zonen.
- . 1928. *Die Südliche Milchstrasse*. *Annalen van de Bosscha-Sterrenwacht*, 2:1. Amsterdam: De Bussy.
- . 1933. *Photographische Photometrie der Nördlichen Milchstrasse*. Publications of the Astronomical Institute of the University of Amsterdam 3. Amsterdam: Stadsdrukkerij.
- . 1942. '[J. Harper, Pseud.] Materialism and Historical Materialism'. *New Essays* 6(2): 9-25.
- . (1944) 1953. *Anthropogenesis: A Study of the Origin of Man*. Amsterdam: North-Holland.
- . 1961. *A History of Astronomy*. London: George Allen and Unwin.
- Pannekoek, Anton, and David Koelbloed. 1949. *Photographic Photometry of the Southern Milky Way*. Publications of the Astronomical Institute of the University of Amsterdam 9. Amsterdam: Stadsdrukkerij.

- Proctor, Richard A. 1883. 'The Photographic Eyes of Science'. *Longman's Magazine* 1(4): 439-462.
- Radman, Zdravko. 2013. 'Beforehand'. In *The Hand, an Organ of the Mind: What the Manual Tells the Mental*, ed. by Zdravko Radman. Cambridge, MA: MIT Press, xix-xxii.
- Roy, Jean-René. 2017. *Unveiling Galaxies: The Role of Images in Astronomical Discovery*. Cambridge: Cambridge University Press
- Schaffer, Simon. 1988. 'Astronomers Mark Time: Discipline and the Personal Equation'. *Science in Context* 2(1): 115-145.
- Scheiner, Julius. 1897. *Die Photographie der Gestirne*. Leipzig: Wilhelm Engelmann.
- Sheehan, William. 1988. *Planets & Perception: Telescopic Views and Interpretations, 1609-1909*. Tucson: The University of Arizona Press.
- Sheehan, William, and Christopher J. Conselice. 2016. *Galactic Encounters: Our Majestic and Evolving Star-System, from the Big Bang to Time's End*. New York: Springer.
- Smith, Robert W. 1991. 'A National Observatory Transformed: Greenwich in the Nineteenth Century'. *Journal for the History of Astronomy* 22(1): 5-20.
- Sohn-Rethel, Alfred. 1989. *Geistige und körperliche Arbeit: zur Epistemologie der abendländischen Geschichte*. Weinheim: VCH Acta Humaniora.
- Tai, Chaokang. 2017. 'Left Radicalism and the Milky Way: Connecting the Scientific and Socialist Virtues of Anton Pannekoek'. *Historical Studies in the Natural Sciences* 47(2): 200-254.
- Tai, Chaokang, and Jeroen van Dongen. 2016. 'Anton Pannekoek's Epistemic Virtues in Astronomy and Socialism: Personae and the Practice of Science'. *BMGN – Low Countries Historical Review* 131(4): 55-70.
- Vertesi, Janet. 2015. *Seeing like a Rover: How Robots, Teams, and Images Craft Knowledge of Mars*. Chicago, IL: University of Chicago Press.
- Wilson, Frank R. 1998. *The Hand: How Its Use Shapes the Brain, Language, and Human Culture*. New York: Pantheon.

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