Anton Pannekoek, Marxist astronomer

Photography, epistemic virtues, and political philosophy in early twentieth-century astronomy

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Introduction

When Harvard University celebrated its tercentenary in 1936, it conveyed honorary degrees to 39 distinguished international scholars. Among the recipients was Dutch astronomer Anton Pannekoek (1873–1960), who was honoured for his 'contributions of high merit in many fields of astronomy'.[1] Among other things, Pannekoek had determined the distances to Milky Way clouds, providing early evidence of the eccentric position of the Sun in the stellar system; introduced a numerical method for calculating the astrophysics of stellar atmospheres; and produced drawings of the Milky Way that were featured in Zeiss Planetariums around the world for decades.[2]

There was also a very different side to Pannekoek. Prior to attending Harvard's tercentenary conference, he addressed the members of the Workers' Socialist Party of the United States: a small but active left com-

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Parts of this introduction combine and revise material published in Chaokang Tai, 'Left Radicalism and the Milky Way: Connecting the Scientific and Socialist Virtues of Anton Pannekoek', *Historical Studies in the Natural Sciences* 47, no. 2 (2017): 200–254, esp. 201–213; Tai, 'The Milky Way as Optical Phenomenon: Perception and Photography in the Drawings of Anton Pannekoek', in *Anton Pannekoek: Ways of Viewing Science and Society*, ed. Chaokang Tai, Bart van der Steen and Jeroen van Dongen (Amsterdam: Amsterdam University Press, 2019), esp. 219–222, 234–235; Chaokang Tai and Jeroen van Dongen, 'Anton Pannekoek's Epistemic Virtues in Astronomy and Socialism: Personae and the Practice of Science', *BMGN — Low Countries Historical Review* 131, no. 4 (2016): 55–70, esp. 55–59.

1. *Science*, 'The Harvard Tercentenary', *Science* 83, no. 2163 (1936): 566–567.

2. Carl Zeiss Jena to Anton Pannekoek, 25 Jul 1927, Archive of the Anton Pannekoek Institute, University of Amsterdam (API); Henry C. King, *Geared to the Stars: The Evolution of Planetariums, Orreries, and Astronomical Clocks*, in collaboration with John R. Millburn (Bristol: Adam Hilger, 1978), 70.

munist movement in Boston.[3] Their members, who turned out in large numbers for the meeting, had a very different reason to be interested in Pannekoek. They knew him as the former party theoretician of the Sozialdemokratische Partei Deutschlands (SPD), the largest socialist party of its time, and as one of the contemporary theoretical leaders of the council communist movement, which they supported.

Throughout the twentieth century, few people have managed to be as influential as Pannekoek in such widely different fields as Marxism and astronomy. The fact that he managed to contribute significantly to both fields makes him a compelling case study for the history of science and the history of political thought. His life and work uniquely capture the fascinating connections between conceptions of nature, society, and their representations in the early decades of the twentieth century. Yet historical research on Pannekoek's astronomy and its relation and connections with his socialism has been conspicuously lacking until very recently.[4]

The goal of this thesis is twofold. The first is to analyse Pannekoek's astronomy in relation to contemporary developments in the discipline. Such an analysis will increase our understanding of a crucial period in the history of astronomy when the field rapidly changed, not only in its description of the heavens, but also in its subject matter, approach, and methods of collaboration. The second is to explore the relations between Pannekoek's astronomical research and his Marxist writings. This not only helps us better understand the methodological and epistemological choices he made in his astronomy, but will also inform us about the broader relations between science and political thought and provide a more unified picture of Pannekoek's life. To achieve these goals, I will not only discuss Pannekoek's scientific research but also investigate his ideas on proper scientific methodology, and use a framework of epistemic virtues to relate his scientific epistemology to his Marxist philosophy.

3. Isaac Rabinowich to Anton Pannekoek, 5 Sep 1936, Archief Anton Pannekoek, International Institute of Social History (IISH/AP), 53/1; Karla Doris Rab, *Role-Modeling Socialist Behavior: The Life and Letters of Isaac Rab.* (Raleigh: Lulu.com, 2010), 55–56 and 202.

4. I mention 'until very recently' because a conference centred around this very subject was organized in 2016 by Jeronimo Voss, Edward van den Heuvel, Jeroen van Dongen, Bart van der Steen, Ralph Wijers, and myself. An edited volume containing selected papers from that conference has subsequently been published as Chaokang Tai, Bart van der Steen and Jeroen van Dongen, eds., *Anton Pannekoek: Ways of Viewing Science and Society* (Amsterdam: Amsterdam University Press, 2019).

Additionally, my own research on the relation between Pannekoek's astronomy and Marxism has been published as Tai and Van Dongen, 'Personae and the Practice of Science'; Tai, 'Left Radicalism and the Milky Way'; 'Milky Way as Optical Phenomenon'.

Anton Pannekoek

Pannekoek had an inconspicuous start of his career, quite similar to that of many Dutch scientists in the early twentieth century. He was born in 1873 in the small rural town of Vaassen in the eastern part of the Netherlands. For his secondary education, he attended the local *Hogere Burgerschool* (HBS) in nearby Apeldoorn, where he developed an interest in astronomy.[5] At the instigation of his teachers, Pannekoek decided to pursue an academic career at Leiden University, where he studied physics and mathematics. He was hired as an observer at the Leiden Observatory in 1899 with the assignment to make precision measurements of stellar coordinates. He was also allowed time to work on his dissertation on the light variation of Algol, which he finished in 1902.[6] Despite the auspicious start of his astronomical career, however, Pannekoek soon became disillusioned with his daily activities in Leiden. The work was tedious and irrelevant, the atmosphere stale and rigid, and he grew frustrated by the observatory director's resistance to innovation. Pannekoek concluded that he was unsuited for the life of an astronomer and, in 1906, quit his position in Leiden to reconsider his career choices.[7] The opportunity to do something completely different came when he was invited to teach historical materialism at the *Parteischule* of the SPD in Berlin.

By this time, Pannekoek had built quite a reputation for himself as a Marxist thinker. He had converted to socialism in 1899 after reading

5. Anton Pannekoek, *Herinneringen: Herinneringen uit de arbeidersbeweging; Sterrenkundige herinneringen*, ed. Ben A. Sijes, Johanna M. Welcker and J. R. van der Leeuw (Amsterdam: Van Gennep, 1982), 229–231. The HBS was a form of secondary education for children from the upper middle class that strongly emphasized the natural sciences. Although it did not grant immediate access to the universities — HBS graduates were required to take additional courses in the classical languages, which took Pannekoek three additional years to complete — many prominent Dutch scientists of the late nineteenth and early twentieth century had graduated from an HBS. For a discussion on the role played by the HBS in the renaissance of Dutch science in the late nineteenth century, see Bastiaan Willink, *De tweede Gouden Eeuw: Nederland en de Nobelprijzen voor natuurwetenschappen, 1870–1940* (Amsterdam: Bert Bakker, 1998); Ad Maas, 'Tachtigers in de wetenschap: Een nieuwe kijk op het ontstaan van de "Tweede Gouden Eeuw" in de Nederlandse natuurwetenschap', *Tijdschrift voor Geschiedenis* 114, no. 3 (2001): 354–376; Maas, 'Civil Scientists: Dutch Scientists between 1750 and 1875', *History of Science* 48, no. 1 (2010): 75–103.

6. Pannekoek, *Herinneringen*, 233–236; Pannekoek, 'Untersuchungen über den Lichtwechsel Algols' (PhD Thesis, Leiden University, 1902).

7. David Baneke, 'Teach and Travel: Leiden Observatory and the Renaissance of Dutch Astronomy in the Interwar Years', *Journal for the History of Astronomy* 41, no. 2 (2010): 167–198, 169–170; Pannekoek, *Herinneringen*, 234–237.

socialist literature and becoming enthralled by utopian thinkers.[8] He became actively involved in the socialist movement, co-founding the Leiden chapter of the Sociaal Democratische Arbeiderspartij (SDAP) and writing articles on Marxist theory. He established himself as a principled and orthodox Marxist on the left wing of the SDAP and often challenged and criticized the tactics of its leaders, which he perceived to be opportunistic and revisionist.[9] Pannekoek's activities impressed Karl Kautsky, the theoretical leader of the SPD, who had arranged the invitation to come to Berlin. Pannekoek's time at the *Parteischule* was short-lived as he was soon prevented from teaching by the Prussian state, but he remained in Berlin to write socialist articles.[10] In Germany, too, Pannekoek settled in the left opposition of the party, especially after his move to Bremen in 1910 where he was instrumental in organizing the radical Bremen left. He criticized the use of parliamentary tactics and the co-operation with trade unions, arguing that the only way to achieve a truly democratic socialist society was through a total revolution of the state, which could only be initiated by the workers themselves. This stance eventually led to a controversy with Kautsky but gained him the support of Lenin and the Bolsheviks.[11]

The start of the First World War in 1914 forced Pannekoek to repatriate to the Netherlands, but he remained in close contact with both the Bremen left and the Bolsheviks. He was elated when he heard about the Bolshevik Revolution of 1917 and the German Revolutions of 1918–1919, although he stressed that the Soviet Union should not be ruled by the Communist Party but by the workers themselves. This criticism led him to be denounced by Lenin, who argued Pannekoek's work was 'particularly

8. See Klaas van Berkel, 'Utopianism in Anton Pannekoek's Socialism and Astronomy', in Tai, Van der Steen and Van Dongen, *Pannekoek: Ways of Viewing*, 81–83. Van Berkel argues that both Pannekoek's astronomy and his socialism emerged from 'the utopian longing for wholeness and purity' (85).

9. Mark A. M. Boekelman, 'The Development of the Social and Political Thought of Anton Pannekoek, 1873–1960: From Social Democracy to Council Communism' (PhD Thesis, University of Toronto, 1980), 45–54; John P. Gerber, *Anton Pannekoek and the Socialism of Workers' Self-Emancipation, 1873–1960* (Dordrecht: Kluwer, 1989), 36–42.

10. For more on the SPD *Parteischule*, see Nicholas Jacobs, 'The German Social Democratic Party School in Berlin, 1906–1914', *History Workshop Journal* 5 (1978): 179–187.

11. John P. Gerber, 'From Left Radicalism to Council Communism: Anton Pannekoek and German Revolutionary Marxism', *Journal of Contemporary History* 23, no. 2 (1988): 169–189; *Pannekoek and Workers' Self-Emancipation*, 72–88, 95–100; Gerrit Voerman, 'Anton Pannekoek: A 'Principled Theorist'', in Tai, Van der Steen and Van Dongen, *Pannekoek: Ways of Viewing*, 56–61; Heinz Schurer, 'Anton Pannekoek and the Origins of Leninism', *Slavonic and East European Review* 41, no. 97 (1963): 327–344.

"solid" and particularly stupid'.[12] For Pannekoek, it was clear that he occupied an increasingly isolated position within the communist movement. He terminated his membership of the Dutch Communist Party and aligned himself with the new council communist movement, which rejected any form of bureaucracy and instead championed complete self-organization by the working class. Pannekoek remained one of the leading theoreticians of council communism for the rest of his life, but the movement itself remained small and struggled to gain support or relevancy.[13]

Despite his continued involvement with Marxism, the second half of Pannekoek's life was primarily devoted to astronomy. Meetings with Karl Schwarzschild and Ejnar Hertzsprung of the Potsdam Observatory in 1909 had reignited his love for the subject and prompted him to engage in astronomical research once again.[14] He became a lecturer in History of Astronomy at Leiden University in 1916 while the prospect of becoming a professional astronomer again came in 1918 when he was offered the position of assistant director at the reorganized Leiden Observatory. After a year of negotiations and delays, however, the Dutch government blocked the hiring, refusing to appoint an outspoken Marxist at a prestigious public university.[15]

12. Vladimir Ilyich Lenin, *'Left-Wing' Communism: An Infantile Disorder* (1920; repr., Moscow: Novosti Press Agency Publishing, 1970), 42. In this pamphlet, Lenin addressed Pannekoek by his pseudonym K. Horner. For more on the conflict between Pannekoek and Lenin, see Gerber, *Pannekoek and Workers' Self-Emancipation*, 132–157; Boekelman, 'Social and Political Thought of Pannekoek', 259–298; Voerman, 'Principled Theorist', 61–68.

13. For more on the development of council communism and Pannekoek's role in this, see Marcel van der Linden, 'On Council Communism', *Historical Materialism* 12, no. 4 (2004): 27–50; Gaard Kets, 'Working-Class Politics in the Bremen Council Republic', in *The German Revolution and Political Theory*, ed. Gaard Kets and James Muldoon (Cham: Palgrave Macmillan, 2019); James Muldoon, 'The Birth of Council Communism', in *The German Revolution and Political Theory*, ed. Gaard Kets and James Muldoon (Cham: Palgrave Macmillan, 2019); Benjamin Ask Popp-Madsen and Gaard Kets, 'Workers' Councils and Radical Democracy: Toward a Conceptual History of Council Democracy from Marx to Occupy', *Polity* 53, no. 1 (2021).

14. Pannekoek, *Herinneringen*, 241–242. A few years earlier, in 1907, Schwarzschild had put Pannekoek forward as a potential candidate for Professor of Mathematics in Göttingen, but this suggestion was rejected because Pannekoek was both a foreigner and a socialist. Karl Schwarzschild to Hendrik A. Lorentz, 9 Jul 1907, Lorentz, prof. dr. H. A., te Haarlem, Noord-Hollands Archief (NHA/HL), 69: 109; Schwarzschild to Lorentz, 15 Jul 1907, Nachlass Karl Schwarzschild, Niedersächsische Staats- und Universitätsbibliothek Göttingen (SUG/KS), Briefe 472.

15. A detailed account of Pannekoek's rejection in Leiden is provided in David Baneke, '"Hij kan toch moeilijk de sterren in de war schoppen": De afwijzing van Anton Pan-

The rejection in Leiden proved to be a blessing in disguise for Pannekoek: he was hired instead by the University of Amsterdam, a municipal rather than a state university, where he could found a new astronomical institute. Since he could not construct an observatory, he modelled the institute after the Astronomical Laboratory in Groningen and dedicated himself to measuring and reducing photographic plates taken by others.[16] The initial focus of the institute was on the structure of the stellar system, which was an established topic in the Netherlands, primarily due to the contributions of Jacobus C. Kapteyn. Soon, however, Pannekoek redirected most of his attention to the newly emerging field of astrophysics of stellar atmospheres, becoming the first astronomer in the Netherlands to do so. He was appointed extraordinary professor in 1925 and ordinary professor in 1932. He also remained interested in the history of astronomy, which became a focal point of his writing during his retirement.[17]

Pannekoek Scholarship

Plenty of historical literature has been written about Pannekoek, but this has almost entirely focused on his political career. Interest in Pannekoek's Marxism had been revived following the protests of May 1968 and the Portuguese Carnation revolution of 1974, which led to the publication of books and anthologies that presented his socialist writings to a new public.[18] Pannekoek became the subject of academic scholarship in the

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nekoek als adjunct-directeur van de Leidse Sterrewacht in 1919', *Gewina* 27, no. 1 (2004): 1–13; Baneke, 'Pannekoek's One Revolution: Anton Pannekoek and the Modernization of the Dutch Astronomical Community', in Tai, Van der Steen and Van Dongen, *Pannekoek: Ways of Viewing*, 91–97 See also Van Berkel, 'Utopianism in Pannekoek's Socialism and Astronomy', 79–80 This would not be the last time that the Dutch government interfered to prohibit socialists from working at state funded universities. In 1920, Albert Einstein's appointment as special visiting professor in Leiden was delayed because he was mistaken for a communist activist with the same last name; and in 1934, mathematician Dirk Jan Struik was blocked from becoming visiting professor at the Delft Institute of Technology because he was a communist. See, respectively, Jeroen van Dongen, 'Mistaken Identity and Mirror Images: Albert and Carl Einstein, Leiden and Berlin, Relativity and Revolution', *Physics in Perspective* 14, no. 2 (2012): 126–177; Gerard Alberts, 'On Connecting Socialism and Mathematics: Dirk Struik, Jan Burgers, and Jan Tinbergen', *Historia Mathematica* 21, no. 3 (1994): 280–305, 281.

16. Pannekoek, *Herinneringen*, 246–249.

17. See e.g. Pannekoek, 'The Discovery of Neptune', *Centaurus* 3, no. 1 (1953): 126–137; Pannekoek, *A History of Astronomy* (New York: Interscience, 1961).

late 1970s and 1980s, which resulted in several dissertations that traced the development of his political thought.[19]

The image of Pannekoek that emerges from these studies is one of a principled and orthodox Marxist who had a scientific approach to the subject. His Marxist philosophy, which he developed early in his career and from which he rarely strayed, was based not only on the writings of Karl Marx and Friedrich Engels, but especially on those of German-American self-taught philosopher Joseph Dietzgen. Following Dietzgen, Pannekoek emphasized that society developed through an interplay of both social and economic circumstances *and* mental factors like religion and education. He also concluded that any attempts by Marxists to predetermine or direct the political actions of workers would only serve to pacify them and diminish their revolutionary tendencies. Instead, he stressed that Marxism should be interpreted as a scientific method for studying society; indeed, he even used the term interchangeably with the terms 'social science' en 'historical materialism'.[20] The goal should be to study society and educate the workers so that they could formulate their own ideas on how the revolution should transpire and how society should be organized. This stance often placed him at odds with socialist leadership and is the reason why he constantly found himself in the left opposition.[21]

18. These include: Hans Manfred Bock, ed., *A. Pannekoek, H. Gorter: Organisation und Taktik der proletarischen Revolution* (Frankfurt am Main: Neue Kritik, 1969); Serge Bricianer, *Pannekoek and the Worker's Councils* (Saint Louis: Telos Press, 1978), originally published in French in 1969; Frits Kool, ed., *Die Linke gegen die Parteiherrschaft* (Olten: Walter-Verlag, 1970); Cajo Brendel, *Anton Pannekoek, theoretikus van het socialisme* (Nijmegen: Socialistische Uitgeverij Nijmegen, 1970); Jaap Kloosterman, ed., *Anton Pannekoek: Partij, raden, revolutie* (Amsterdam: Van Gennep, 1972); Duncan Alexander Smart, ed., *Pannekoek and Gorter's Marxism* (London: Pluto Press, 1978).

19. Three dissertations focus entirely on Pannekoek: Boekelman, 'Social and Political Thought of Pannekoek'; Corrado Malandrino, *Scienza e socialismo: Anton Pannekoek (1873–1960)* (Milan: Franco Angeli, 1987); Gerber, *Pannekoek and Workers' Self-Emancipation.* Others discussed Pannekoek's politics in the context of the broader Dutch left, German Bauman, *De tribunisten: De revolutionaire marxisten van Nederland* (Moscow: Progres, 1988), translated from Russian dissertation from 1981; Philippe Bourrinet, *The Dutch and German Communist Left (1900–68): 'Neither Lenin nor Trotsky nor Stalin!'; 'All Workers Must Think for Themselves!'* (Leiden: Brill, 2017), revised version of French dissertation from 1988; Henny Buiting, *Richtingen- en partijstrijd in de SDAP. Het onstaan van de Sociaal-Democratische Partij in Nederland (SDP)* (Amsterdam: Stichting Beheer IISG, 1989); Frank Kalshoven, *Over marxistische economie in Nederland, 1883–1939* (Amsterdam: Thesis Publishers, 1993).

20. Gerber, *Pannekoek and Workers' Self-Emancipation*, 22.

21. Tai and Van Dongen, 'Personae and the Practice of Science'.

Those who have studied Pannekoek's socialism, however, have all but neglected his astronomical research.[22] The lack of interest in finding the connections between his astronomy and Marxism can partially be attributed to his own attempts to keep his two careers separate. In his astronomical papers, there was never any mention of his political ideas, and he hardly ever discussed politics with colleagues.[23] Likewise, in his political writings, he rarely mentioned his scientific background. Moreover, starting in 1918, he regularly wrote his socialist articles under various pen names to further compartmentalize his two careers. He even wrote two memoirs that separately discussed his careers in the workers' movement and in astronomy.[24] This strategy was successful in convincing both contemporaries and later historians that his two lives could indeed be kept apart. The British Marxist historian Eric Hobsbawm even used Pannekoek as an example to illustrate the apparent divide between political philosophy and the natural sciences in the early twentieth century. He argued that

> it was quite possible in [this] (or any) period to be both a distinguished astronomer and a revolutionary Marxist, like A. Pannekoek ..., whose professional colleagues doubtless thought his politics as irrelevant to his astronomy as his comrades felt his astronomy to be to the class struggle.[25]

22. This is in stark contrast to those who have studied his two closest socialist compatriots, the poets Herman Gorter and Henriette Roland Holst. In their case, historians have actively searched for the connections between their socialism and literary work. For Gorter, see Herman de Liagre Böhl, *Met al mijn bloed heb ik voor U geleefd: Herman Gorter, 1864–1927* (Amsterdam: Balans, 1996); Hub Zwart, 'Poetry, Science and Revolution: The Enigma of Herman Gorter's *Pan*', *Journal of Dutch Literature* 10, no. 1 (2019): 24–49; for Roland Holst, see Elsbeth Etty, *Liefde is heel het leven niet: Henriette Roland Holst, 1869–1952* (Amsterdam: Balans, 1996).

23. He was, for example, acquainted with Marxist physicist Léon Rosenfeld for years before they realized their shared Marxist conviction. See the Pannekoek–Rosenfeld correspondence, Léon Rosenfeld Papers, Niels Bohr Archive, University of Copenhagen (NBA/LR), box 1, folder 2.

24. Pannekoek, *Herinneringen*. The two memoirs were written in the winter of 1944 and were intended for his family. They were published together with introductions by Ben Sijes for the socialist memoirs, and Edward van den Heuvel for the astronomical memoirs. The choice to not attempt to write an introduction that encompassed both was criticized in Klaas van Berkel, review of *Herinneringen*, by Anton Pannekoek, *BMGN — Low Countries Historical Review* 99, no. 3 (1984).

25. Eric Hobsbawm, *The Age of Empire, 1875–1914* (New York: Vintage Books, 1989), 268–269. Hobsbawm used the example of Pannekoek to contrast with the pervasive influence of political ideology in the social sciences.

Yet, as we have seen, Pannekoek did suffer the consequences of his political affiliation at various times in his astronomical career. His self-compartmentalization into two careers should be interpreted as an effort to minimize such conflicts.[26] There were clear links between his socialism and astronomy, as Pannekoek himself asserted. When asked about their relation in 1957, he answered: 'Interaction existed in so far, that the method of natural science, which I had learned thoroughly, helped me to discover the science of society in Marxism; and that has remained the foundation of my work.'[27] Accordingly, to appreciate Pannekoek's idiosyncratic approach to Marxism, an analysis of his scientific methodology is indispensable. But here, we run into the problem that his contributions to astronomy have not received much attention from historians of science either. The literature on this subject is limited to short biographical articles and obituaries,[28] and snippets included in more general histories of astronomy.[29] These sources offer little more than a superficial indication of his methodology in astronomy. Taken together, this makes

26. Van Berkel, 'Utopianism in Pannekoek's Socialism and Astronomy'; Edward P. J. van den Heuvel, 'Anton Pannekoek's Astronomy in Relation to his Political Activities, and the Founding of the Astronomical Institute of the University of Amsterdam', in Tai, Van der Steen and Van Dongen, *Pannekoek: Ways of Viewing*.

27. Pannekoek, *Herinneringen*, 16–17. Translated from Dutch.

28. Short biographical articles discussing Pannekoek's astronomical career include: Edward P. J. van den Heuvel, 'Pannekoek: Socialist en sterrekundige', in *Een Brandpunt van geleerdheid in de hoofdstad: de Universiteit van Amsterdam rond 1900 in vijftien portretten*, ed. J. C. H. Blom (Hilversum: Verloren, 1992); Albert van Helden, 'Antonie Pannekoek, 1873–1960', in *A History of Science in the Netherlands: Survey, Themes and Reference*, ed. Klaas van Berkel, Albert van Helden and Lodewijk Palm (Leiden: Brill, 1998); Marcel Minnaert, 'Pannekoek, Antonie', in *Complete Dictionary of Scientific Biography*, ed. Charles C. Gillispie, vol. 10, 289–291 (Detroit: Charles Scribner's Sons, 2008); Klaas van Berkel, 'Pannekoek, Antonie (1873–1960)', in *Biografisch Woordenboek van Nederland*, ed. Ivo Schöffer, vol. 5, 384–387 (The Hague: Instituut voor Nederlandse Geschiedenis, 2001); Christoffel Waelkens, 'Pannekoek, Antonie', in *Biographical Encyclopedia of Astronomers*, ed. Thomas Hockey, vol. 2, 1641–1643 (New York: Springer, 2014); Willink, *De tweede Gouden Eeuw*, 140–144. Obituaries include: Bart J. Bok, 'Two Famous Dutch Astronomers', *Sky and Telescope* 20, no. 2 (1960): 74–76; Gale Bruno van Albada, 'In Memoriam Prof. Dr. A. Pannekoek (II)', *Folia Civitis* 13, no. 27 (1960): 2–3; Herman Zanstra, 'Levensbericht van Antonie Pannekoek (2 januari 1873–28 april 1960)', *Jaarboek der Koninklijke Nederlandse Akademie van Wetenschappen* 1959–1960 (1960): 328–330; Henri L. Vanderlinden, 'In Memoriam Prof. A. Pannekoek', *Jaarboek van de Koninklijke Vlaamsche Academie voor Wetenschappen, Letteren en Schone Kunsten van Belgie* 22 (1960): 235–236.

29. Pannekoek's astrophysical research is discussed in John B. Hearnshaw, *The Analysis of Starlight: Two Centuries of Astronomical Spectroscopy*, 2nd ed. (New York: Cambridge University Press, 2014), 138–146, 160–162, 257–277. His career as part of the broader astronomical community in the Netherlands is discussed in David Baneke, *De ontdekkers*

clear that a detailed investigation of Pannekoek's astronomical research is sorely needed. Not only because it will enable the comparison with his socialism, but also because it promises to provide valuable insight into the contemporaneous development of astronomy and astrophysics and how that was part of the larger history of knowledge in the early twentieth century.

The New Astronomy

The early twentieth century, when Pannekoek was active as an astronomer, was an exciting time in astronomy. It underwent several developments that transformed not only the content but also the practice of the field. Three of the most impactful transformations during this period were the widespread implementation of astrophotography, the overhaul of ideas on the size and structure of the universe, and the rise of astrophysics. Since Pannekoek was deeply involved in all three of these episodes, the study of his life and astronomy provides an excellent opportunity to study and appreciate this transformative episode in the history of astronomy.

Astronomy had been one of the first scientific disciplines to embrace photography in the mid-nineteenth century, but, as historians of astronomy and photography have shown, it was initially the domain of wealthy self-funded astronomers, who took the freedom to experiment with various photographic techniques.[30] Many astronomers, especially

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van de hemel: De Nederlandse sterrenkunde in de twintigste eeuw (Amsterdam: Prometheus Bert Bakker, 2015).

30. John Lankford, 'Amateurs and Astrophysics: A Neglected Aspect in the Development of a Scientific Specialty', *Social Studies of Science* 11, no. 3 (1981): 275–303; Lankford, 'The Impact of Photography on Astronomy', in *The General History of Astronomy, Volume 4: Astrophysics and Twentieth-Century Astronomy to 1950: Part A*, ed. Owen Gingerich (Cambridge: Cambridge University Press, 1984); Sarah Kate Gillespie, 'John William Draper and the Reception of Early Scientific Photography', *History of Photography* 36, no. 3 (2012): 241–254. In much of the historical literature on this subject, the distinction is made between amateur and professional astronomers. It is questionable, however, how meaningful it is to draw the distinction along these lines in nineteenth-century astronomy, since both groups dedicated much of their life to the field and were considered each others peers. For a critical discussion on the usefulness of this distinction, see Stephen Case, *Making Stars Physical: The Astronomy of Sir John Herschel* (Pittsburgh: University of Pittsburgh Press, 2018), 11–15; Joshua Nall, *News from Mars: Mass Media and the Forging of a New Astronomy, 1860–1910* (Pittsburgh: University of Pittsburgh Press, 2019), 12–15, 179–181, 192 n. 25.

those working for large visual observatories, however, had genuine epistemic concerns about the trustworthiness and applicability of astrophotography in scientific research.[31] Even in the depiction of visually striking objects, like nebulae, planetary and lunar surfaces, or the Solar corona, astronomers initially preferred drawings and diagrams based on visual observations over photography. Such observations were considered more accurate because the human eye was thought to be better at capturing large scale structures and evaluating differences in brightness. When photography was eventually applied to these subjects, toward the end of the nineteenth century, it was still rare for photographs depicting astronomical objects to find their way into professional publications. Instead, photographic plates were used mainly for precise measurement with the results being presented in the form of drawings and diagrams, similar to how visual observations had been used.[32] Pannekoek's use of astrophotography in representing the Milky Way a few decades later is interesting in comparison with these cases because it differed in a crucial way. Pannekoek did not wish to rely on regular photography to capture the Milky Way light, as that would resolve it into the individual stars that comprised it. Instead, he had to develop the method of extrafocal photographic photometry to mimic the workings of the human eye.

31. See e.g. John Lankford, 'Photography and the 19th-Century Transits of Venus', *Technology and Culture* 28, no. 3 (1987): 648–657; Holly Rothermel, 'Images of the Sun: Warren De La Rue, George Biddell Airy and Celestial Photography', *British Journal for the History of Science* 26, no. 2 (1993): 137–169; Alex Soojung-Kim Pang, '"Stars Should Henceforth Register Themselves": Astrophotography at the Early Lick Observatory', *British Journal for the History of Science* 30, no. 2 (1997): 177–202; Jimena Canales, 'Photogenic Venus: The "Cinematographic Turn" and Its Alternatives in Nineteenth-Century France', *Isis* 93, no. 4 (2002): 585–613; Jennifer Tucker, *Nature Exposed: Photography as Eyewitness in Victorian Science* (Baltimore: Johns Hopkins University Press, 2005); Omar W. Nasim, 'James Nasmyth's Lunar Photography: Or on Becoming a Lunar Being, Without the Lunacy', in *Selene's Two Faces: From 17th Century Drawings to Spacecraft Imaging*, ed. Carmen Pérez González (Leiden: Brill, 2018).

32. For the use of photography in research on nebulae, see Omar W. Nasim, *Observing by Hand: Sketching the Nebulae in the Nineteenth Century* (Chicago: University of Chicago Press, 2013); for Mars, see K. Maria D. Lane, *Geographies of Mars: Seeing and Knowing the Red Planet* (Chicago: University of Chicago Press, 2011); Tucker, *Nature Exposed*; for the Moon, see Charlotte Bigg, 'Of Blurs, Maps and Portraits: Photography and the Moon', in *Selene's Two Faces: From 17th Century Drawings to Spacecraft Imaging*, ed. Carmen Pérez González (Leiden: Brill, 2018); for the Solar corona, see Rothermel, 'Images of the Sun'; Barbara J. Becker, 'Priority, Persuasion, and the Virtue of Perseverence: William Huggins's Efforts to Photograph the Solar Corona without an Eclipse', *Journal for the History of Astronomy* 31, no. 3 (2000): 223–243; Alex Soojung-Kim Pang, *Empire and the Sun: Victorian Solar Eclipse Expeditions* (Stanford: Stanford University Press, 2002).

Photography had one crucial advantage over visual observations: photographic plates could be taken in bulk and stored for later use.[33] As such, they could be distributed to different locations, enabling a division of labour among astronomical institutions as part of the *industrialization* of astronomy.[34] This division of labour was significant because extracting usable scientific information from photographic plates through measurement and calibration was very labour intensive.[35] Many photographic observatories produced far more photographic plates than they could measure on their own, which made it possible to found astronomical institutes that lacked any kind of observatory. A ground-breaking example was the creation of the Astronomical Laboratory of Jacobus C. Kapteyn in Groningen in 1896. Kapteyn began a collaboration with David Gill of the Cape Observatory in which photographic plates taken in South Africa were shipped to the Netherlands where they were measured and reduced. The success of the resulting *Cape Photographic Durchmusterung*, published 1896–1900, firmly established the value of astrophotography for positional astronomy and highlighted the advantages of dividing astronomical labour.[36] It encouraged other institutes to follow the path of Kapteyn's as-

33. The possibility to record observations for later use was useful for short events like Solar eclipses and Venus transits but also for creating photographic atlases that could be used as an archive for future astronomers, such as the *Carte du Ciel*. For the former, see *Empire and the Sun*; Canales, 'Photogenic Venus'; Jessica Ratcliff, *The Transit of Venus Enterprise in Victorian Britain* (London: Pickering & Chatto, 2008). For the latter, see Lorraine Daston, 'The Immortal Archive: Nineteenth-Century Science Imagines the Future', in *Science in the Archives: Pasts, Presents, Futures*, ed. Lorraine Daston (Chicago: University of Chicago Press, 2017).

34. Stephen G. Brush, 'Looking Up: The Rise of Astronomy in America', *American Studies* 20, no. 2 (1979): 41–67, 51–55; John Lankford and Ricky L. Slavings, 'The Industrialization of American Astronomy, 1880–1940', *Physics Today* 49, no. 1 (1996): 34–40; Alex Soojung-Kim Pang, 'The Industrialization of Vision in Victorian Astronomy', in *Imagination Des Himmels*, ed. Franziska Brons (Berlin: Akademie Verlag, 2007).

35. Charlotte Bigg, 'Photography and Labour History of Astrometry: The Carte du Ciel', in *The Role of Visual Representations in Astronomy: History and Research Practice*, ed. Klaus Hentschel and Axel D. Wittmann (Thun: Verlag Harri Deutsch, 2000); Omar W. Nasim, 'Handling the Heavens: Things and the Photo-Objects of Astronomy', in *Photo-Objects: On the Materiality of Photographs and Photo Archives in the Humanities and Sciences*, ed. Julia Bärnighausen et al. (Berlin: Edition Open Access, 2019).

36. Lankford, 'The Impact of Photography on Astronomy'. For more on the *Cape Photographic Durchmusterung* and the collaboration between Gill and Kapteyn, see Anton Pannekoek, 'J. C. Kapteyn en zijn astronomisch werk', *Wetenschappelijke Bladen* 1 (1923): 257–295, 262–266; C. Andrew Murray, 'David Gill And Celestial Photography', in *Mapping the Sky: Past Heritage and Future Directions*, ed. Suzanne Debarbat, 143–148, International

tronomical laboratory.[37] Pannekoek's astronomical institute in Amsterdam was one of these, and the photographic projects initiated there serve to illustrate the versatile ways in which the distribution of photographic plates could benefit such institutions.

The *Cape Photographic Durchmusterung* was one of several comprehensive star catalogues that were produced in the second half of the nineteenth century. This large increase of data had a significant impact on theories on the size and composition of the universe, which were completely overhauled in the period 1900–1931. At the turn of the century, the generally accepted idea was that there was only a single rather small star system in which the Sun was located near the centre. By 1931, however, the Sun was thought to be located at the outskirts of a large rotating Milky Way galaxy that was only one of many galaxies in a vast expanding universe. These changes were the result of various developments and debates coming together in the 1920s. These included the question of the existence of external galaxies, the debate on the size and structure of our galaxy, and the discovery of interstellar absorption. These episodes, both individually and as a whole, have been extensively researched by historians of science.[38] But these have focused almost exclusively on the developments as they took place in the United States, and often in the context of the 1920

Astronomical Union Symposium 133 (Dordrecht: Kluwer, 1988); Michael Feast, 'Kapteyn and South Africa', in *The Legacy of J. C. Kapteyn: Studies on Kapteyn and the Development of Modern Astronomy*, ed. Pieter C. van der Kruit and Klaas van Berkel (Dordrecht: Kluwer, 2000); Pieter C. van der Kruit, *Jacobus Cornelius Kapteyn: Born Investigator of the Heavens* (Cham: Springer, 2015), chap. 6.

37. Carl Ludvig Charlier adopted a similar strategy in Uppsala. See Gustav Holmberg, *Reaching for the Stars: Studies in the History of Swedish Stellar and Nebular Astronomy, 1860–1940* (Lund: Division of History of Ideas and Sciences, Lund University, 1999), 58–67.

38. For general overviews, see Richard Berendzen, Richard Hart and Daniel Seeley, *Man Discovers the Galaxies* (New York: Science History Publications, 1976); Robert W. Smith, *The Expanding Universe: Astronomy's 'Great Debate', 1900–1931* (Cambridge: Cambridge University Press, 1982); for external galaxies, see Norriss S. Hetherington, 'Adriaan van Maanen and Internal Motions in Spiral Nebulae: A Historical Review', *Quarterly Journal of the Royal Astronomical Society* 13, no. 1 (1972): 25–39; Richard Berendzen and Richard Hart, 'Adriaan van Maanen's Influence on the Island Universe Theory', *Journal for the History of Astronomy* 4, nos. 1–2 (1973): 46–56, 73–98; Michael Hoskin, 'Ritchey, Curtis and the Discovery of Novae in Spiral Nebulae', *Journal for the History of Astronomy* 7, no. 1 (1976): 47–53; Robert W. Smith, 'Beyond the Galaxy: The Development of Extragalactic Astronomy 1885–1965, Part 1', *Journal for the History of Astronomy* 39, no. 1 (2008): 91–119; Smith, 'Beyond the Galaxy: The Development of Extragalactic Astronomy 1885–1965, Part 2', *Journal for the History of Astronomy* 40, no. 1 (2009): 71–107 for the structure of our galaxy, see Owen Gingerich, 'Through Rugged Ways to Galaxies', *Journal for the History*

'Great Debate' on 'The Scale of the Universe' between Harlow Shapley, who argued for a single large galaxy, and Heber D. Curtis, who argued for a small galaxy that was one of many galaxies.[39] As a result, these histories tend to ignore research conducted in other places. By investigating Pannekoek's contributions to statistical astronomy, we get an impression of the debate as it played out in the Netherlands, which is particularly relevant because Dutch astronomers like Kapteyn, Pannekoek, Cornelis Easton, and Jan Oort contributed to the subject in important ways.

The final transformation concerns the rise of astrophysics as a topic of research in the mid-nineteenth century. Whereas astronomy had traditionally focused on the exact location of stars and movement of planets, the new astrophysics was concerned with the physical properties of the stars themselves. Like with astrophotography, this new field was initially explored by self-funded astronomers.[40] These early astrophysicists explored spectroscopic techniques to investigate the spectra of the Sun and stars, which were classified and compared with spectra created in terrestrial laboratories in an effort to determine the chemical properties of the stars.[41] As more and better stellar spectra were catalogued at the begin-

of Astronomy 21, no. 1 (1990): 77–88; E. Robert Paul, *The Milky Way Galaxy and Statistical Cosmology, 1890–1924* (Cambridge: Cambridge University Press, 1993); Owen Gingerich, 'Kapteyn, Shapley, and Their Universes', in *The Legacy of J. C. Kapteyn: Studies on Kapteyn and the Development of Modern Astronomy*, ed. Pieter C. van der Kruit and Klaas van Berkel (Dordrecht: Kluwer, 2000); Robert W. Smith, 'Beyond the Big Galaxy: The Structure of the Stellar System, 1900–1952', *Journal for the History of Astronomy* 37, no. 3 (2006): 307–342; for interstellar absorption, see Daniel H. Seeley and Richard Berendzen, 'The Development of Research in Interstellar Absorption, c. 1900–1930', *Journal for the History of Astronomy* 3, nos. 1–2 (1972): 52–64, 75–86.

39. For more on the 'Great Debate', see Michael Hoskin, 'The "Great Debate": What Really Happened', *Journal for the History of Astronomy* 7, no. 3 (1976): 169–182; Smith, *The Expanding Universe*, 77–90; Virginia Trimble, 'The 1920 Shapley–Curtis Discussion: Background, Issues, and Aftermath', *Publications of the Astronomical Society of the Pacific* 107, no. 718 (1995): 1133–1144.

40. Lankford, 'Amateurs and Astrophysics'; Karl Hufbauer, 'Amateurs and the Rise of Astrophysics, 1840–1910', *Berichte zur Wissenschaftsgeschichte* 9, no. 3 (1986): 183–190.

41. Simon Schaffer, 'Where Experiments End: Tabletop Trials in Victorian Astronomy', in *Scientific Practice: Theories and Stories of Doing Physics*, ed. Jed Z. Buchwald (Chicago: University of Chicago Press, 1995); Matthias Dörries, 'Heinrich Kayser as Philologist of Physics', *Historical Studies in the Physical and Biological Sciences* 26, no. 1 (1995): 1–33, 16–31; Barbara J. Becker, *Unravelling Starlight: William and Margaret Huggins and the Rise of the New Astronomy* (Cambridge: Cambridge University Press, 2011); Hearnshaw, *Analysis of Starlight*, 33–62; Robert W. Smith, 'Astronomy in the Time of Pannekoek and Pannekoek as an Astronomer of his Times', in Tai, Van der Steen and Van Dongen, *Pannekoek: Ways of Viewing*, 110–114.

ning of the twentieth century, it became possible to correlate empirically various spectral properties of stars with one another, initiating what has been called 'The Great Correlation Era'.[42] A more theoretical and quantitative approach to astrophysics became possible with the formulation of the ionization equation by Indian astrophysicist Meghnad Saha in 1920 and its subsequent further development. While historians of astronomy have certainly looked at many of these developments, much is still left unexplored.[43] Pannekoek's astrophysics, for example, has received only a passing mention in many of these histories, which means the context and impact of his research have remained uncharted. This is regrettable because he made significant contributions to the subject for which he was praised by his contemporaries.[44] Moreover, he had a profound impact on the future of Dutch astronomy, as he effectively founded the 'Dutch School of Astrophysics' when he redirected his attention to the subject.[45] Thus, an investigation of Pannekoek's contributions and approach to astrophysics is certainly warranted.

Science and Marxism

A close analysis of Pannekoek's astronomical research can provide crucial insight into the transformation of astronomy and how this impacted its daily practice and methodology. Additionally, it also opens up new avenues to explore the connections between his astronomy and Marxism and situate both in the longer historiography of knowledge. Moreover, a study of their relation reaffirms how moral and political values mani-

42. David H. DeVorkin, 'Extraordinary Claims Require Extraordinary Evidence: C. H. Payne, H. N. Russell and Standards of Evidence in Early Quantitative Spectroscopy', *Journal of Astronomical History and Heritage* 13, no. 2 (2010): 139–144.
43. See e.g. David H. DeVorkin and Ralph Kenat, 'Quantum Physics and the Stars I: The Establishment of a Stellar Temperature Scale', *Journal for the History of Astronomy* 14, no. 2 (1983): 102–132; DeVorkin and Kenat, 'Quantum Physics and the Stars II: Henry Norris Russell and the Abundances of the Elements in the Atmospheres of the Sun and Stars', *Journal for the History of Astronomy* 14, no. 3 (1983): 180–222; Ralph Kenat and David H. DeVorkin, 'Quantum Physics and the Stars (III): Henry Norris Russell and the Search for a Rational Theory of Stellar Spectra', *Journal for the History of Astronomy* 21, no. 2 (1990): 157–186; Hearnshaw, *Analysis of Starlight*.
44. See e.g. William Marshall Smart, 'Address: Delivered by the President, Professor W. M. Smart, on the Award of the Gold Medal to Professor Antonie Pannekoek', *Monthly Notices of the Royal Astronomical Society* 111, no. 2 (1951): 245–264; Bok, 'Two Famous Dutch Astronomers'.
45. Minnaert, 'Pannekoek, Antonie'; Baneke, 'Pannekoek's One Revolution'.

fest themselves in scientific methodologies.[46] Although excellent historical research exists on the interface of socialism and science, it has initially focused mainly on the context of communist state ideologies and its influence on scientists both within and outside of communist countries.[47] Such scholarship has been effective in uncovering how communist politics interfered with the scientific process during the Cold War, but it has provided only a limited view of the various ways in which Marxism and science have been connected. Marxism encompasses more than just a political system and has been developed in places beyond the Soviet Union. Indeed recent scholarship has revealed a myriad of different ways in which science and Marxism were related throughout history that extended well beyond state influence alone.[48] This raises the question of which connections between political thought and scientific work can be revealed

46. See also Margaret C. Jacob, *The Newtonians and the English Revolution, 1689–1720* (Ithaca, NY: Cornell University Press, 1976); Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life: Including a Translation of Thomas Hobbes, Dialogus Physicus de Natura Aeris by Simon Schaffer* (Princeton: Princeton University Press, 1985); Iwan Rhys Morus, 'What Happened to Scientific Sensation?', *European Romantic Review* 22, no. 3 (2011): 389–403; Ad J. P. Maas, 'Johan Rudolph Thorbecke's Revenge: Objectivity and the Rise of the Dutch Nation State', in *Epistemic Virtues in the Sciences and the Humanities*, ed. Jeroen van Dongen and Herman Paul (Cham: Springer, 2017).

47. See e.g. David Joravsky, *Soviet Marxism and Natural Science: 1917–1932* (New York: Columbia University Press, 1961); Loren R. Graham, *Science, Philosophy, and Human Behavior in the Soviet Union* (New York: Columbia University Press, 1989); Kendall E. Bailes, *Science and Russian Culture in an Age of Revolutions: V. I. Vernadsky and His Scientific School, 1863–1945* (Bloomington: Indiana University Press, 1990); Alexei Kojevnikov, 'The Phenomenon of Soviet Science', *Osiris* 23 (2008): 115–135; Fa-ti Fan, 'Science, State, and Citizens: Notes from Another Shore', *Osiris* 27 (2012): 227–249; Astrid Elbers, 'De relaties tussen Nederlandse astronomen en hun Sovjetcollega's tijdens de Koude Oorlog: Tussen pragmatisme en idealisme', *Studium* 5, no. 1 (2012): 15–33. Perhaps the best known and most notorious episode of communist state influence on scientific development is the Lysenko controversy, the literature on which is vast. Recent articles that provide a good overview of the history and historiography of this controversy are Nikolai Krementsov and William deJong-Lambert, '"Lysenkoism" Redux:' in *The Lysenko Controversy as a Global Phenomenon, Volume 1: Genetics and Agriculture in the Soviet Union and Beyond*, ed. William deJong-Lambert and Nikolai Krementsov (Cham: Palgrave Macmillan, 2017); Michael D. Gordin, 'Lysenko Unemployed: Soviet Genetics after the Aftermath', *Isis* 109, no. 1 (2018): 56–78.

48. See e.g. Alberts, 'Connecting Socialism and Mathematics'; Nick Hopwood, 'Biology between University and Proletariat: The Making of a Red Professor', *History of Science* 35, no. 4 (1997): 367–424; Peter Galison, 'The Assassin of Relativity', in *Einstein for the 21st Century: His Legacy in Science, Art, and Modern Culture*, ed. Peter Galison, Gerald James Holton and Silvan S. Schweber (Princeton: Princeton University Press, 2008).

in the case of Pannekoek. Can we get a better understanding of both Pannekoek's astronomy and his Marxism if we investigate how they might relate to one another? And conversely and more broadly, what can the case of Pannekoek tell us about the relation between political philosophy and natural science in general?

One of the direct ways in which Marxism is reflected in the practice of science was through its use of analogy. Alexei Kojevnikov has shown, for example, how in condensed matter physics, the socialist concept of collectivism served as a powerful metaphor to explain the collective behaviour of electrons in metals, crystals and plasmas. The implementation of the metaphor depended on both the physical problem at hand and on the conceptions physicists had of collectivism. To appeal to a wider circle of physicists beyond socialists and leftists, however, these metaphors had to be purged of their overt political connotations and transformed into more neutral language.[49] As Kojevnikov indicates: 'The effective invisibility so achieved suggests that more cases of this sort will be found .... It might prove to be a widespread common form of socialist legacy.'[50] Thus it is worthwhile to search for similar hidden metaphors in the astronomical work of Pannekoek,[51] since he too would likely have employed concealing tactics to maintain the outward separation between his political activities and his scientific career.[52]

Alternatively, aspects of science can be interpreted as dialectic materialism in practice. As Anja Skaar Jacobson has argued, this was the case in the work of Belgian physicist Léon Rosenfeld, who vehemently defended the Copenhagen interpretation of quantum mechanics because he conceived the concept of complementarity, which is central to the Copenhagen interpretation, as a practical implementation of the dialectic method. Notably, he mostly used this Marxist defence of complementarity against attacks from Soviet physicists who considered the concept to be ideal-

49. Alexei Kojevnikov, 'Freedom, Collectivism, and Quasiparticles: Social Metaphors in Quantum Physics', *Historical Studies in the Physical and Biological Sciences* 29, no. 2 (1999): 295–331; Kojevnikov, 'David Bohm and Collective Movement', *Historical Studies in the Physical and Biological Sciences* 33, no. 1 (2002): 161–192.
50. Kojevnikov, 'Bohm and Collective Movement', 192.
51. This has also been suggested in Kalshoven, *Marxistische economie in Nederland*, 218.
52. Conversely, Herman Gorter openly sought to connect science and politics through his use of liquid crystal chemistry as a metaphor for social change in his socialist poetry. Hub Zwart, 'Revolutionary Poetry and Liquid Crystal Chemistry: Herman Gorter, Ada Prins and the Interface between Literature and Science', *Foundations of Chemistry*, 2020.

ist and subjective instead of materialist and objective.[53] Conversely, Pannekoek interpreted dialectic materialism primarily as a scientific method for studying the historical development of societies.[54] He contrasted this method with the method of mechanical materialism, as was commonly used in the natural sciences. Mechanical materialism, he argued, was unsuited for analysing human society and behaviour because it failed to take into account how the human mind processed ideas and social circumstances.[55] He was less outspoken, however, about whether dialectic materialism was preferable for the natural sciences as well. A close analysis of Pannekoek's astronomical research can provide valuable insight into this question.

The study of the relation between science and Marxism as a philosophy has not yet received the attention that it deserves. As Michael Gordin reminds us: 'In terms of scale and influence, [dialectic materialism] was one of the twentieth century's most vigorous philosophies of science, and its history ought to be incorporated into the narratives of the history of philosophy of science that we now have.'[56] Gordin contributed to this cause by studying the life and philosophy of the Prague-born philosopher and historian of science Arnošt Kolman. A complicating factor with Kolman, however, was his deep involvement with Soviet Party politics, making it impossible to determine how sincere he was in many of his philosophical publications.[57] Pannekoek, on the other hand, was an extremely principled Marxist who regularly gave up political influence for the sake of theoretical purity.[58] He thus provides an excellent opportunity to study how dialectic materialism is reflected in scientific epistemology and practice.

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53. Anja Skaar Jacobsen, 'Léon Rosenfeld's Marxist Defense of Complementarity', *Historical Studies in the Physical and Biological Sciences* 37 (Suppl. 2007): 3–34.
54. See Gerber, *Pannekoek and Workers' Self-Emancipation*, 21–27; Bart van der Steen, '"A New Scientific Conception of the Human World": Anton Pannekoek's Understanding of Scientific Socialism', in Tai, Van der Steen and Van Dongen, *Pannekoek: Ways of Viewing*; Annemarie Rullens, 'From Science to Science: Anton Pannekoek, Willem Bonger, and Scientific Socialism', in Tai, Van der Steen and Van Dongen, *Pannekoek: Ways of Viewing*.
55. David Baneke, *Synthetisch denken: Natuurwetenschappers over hun rol in een moderne maatschappij, 1900–1940* (Hilversum: Verloren, 2008), 167–169. Pannekoek's distinction between dialectic materialism and mechanical materialism will be further developed in Chapter 2.
56. Michael D. Gordin, 'The Trials of Arnošt K.: The Dark Angel of Dialectical Materialism', *Historical Studies in the Natural Sciences* 47, no. 3 (2017): 320–348, 346.
57. Ibid., 346–348.
58. Voerman, 'Principled Theorist'.

Epistemic Virtues and Scholarly Personae

To explore the connections between Pannekoek's astronomy and Marxism, we will focus on his 'epistemic virtues'. Epistemic virtues, such as objectivity, thoroughness, and trained judgement, can be imagined as moral guidelines for the practice of scientific research. They are *epistemic* in that they indicate how knowledge should be extracted from the investigation of nature and what the role of the scientist is in this process; they are *virtues* because they provide a moral imperative for this. Although epistemic virtues are often implicit, they are always normative, and as such, they are present beneath the surface of scientific publications: in the assessment of other researchers, in the explanation of methodology, or in the representation of results. Likewise, traits ascribed to the scientific persona can be found by looking at how scientists and scholars praised or criticized their colleagues, but also in the way that they defended themselves against criticism.[59]

Epistemic virtues and scientific or scholarly personae have been important topics of historical research in recent years as a way of exploring how scientific practice can be informed and directed by shared ideals, morals, and ambitions of researchers.[60] In the case of scientific and scholarly personae, historians have described different but related ideas of how personae were envisioned and shown how investigating these can aid in understanding science and scholarship historically. Scientific personae have, for example, been construed as culturally shared scientific identities that provided a template for what it meant to be a scientist. By self-fashioning in relation to these personae, scientists could then delineate their personal identity, shape their public image, or indicate the scholarly tradition to which they wished to belong.[61] They could even be deployed to justify characteristics that might otherwise be perceived as flaws. Gadi Algazi

59. Herman Paul, 'What Is a Scholarly Persona? Ten Theses on Virtues, Skills, and Desires', *History and Theory* 53, no. 3 (2014): 348–371, 363–365; Tai and Van Dongen, 'Personae and the Practice of Science'; Léjon Saarloos, 'Virtue and Vice in Academic Memory: Lord Acton and Charles Oman', *History of Humanities* 1, no. 2 (2016): 339–354.

60. See e.g. Lorraine Daston and H. Otto Sibum, eds., 'Scientific Personae and their Histories', special issue, *Science in Context* 16, nos. 1–2 (2003): 1–269; Herman Paul, ed., 'Scholarly Personae: Repertoires and Performances of Academic Identity', special issue, *BMGN—Low Countries Historical Review* 131, no. 4 (2016): 1–154; Jeroen van Dongen and Herman Paul, eds., *Epistemic Virtues in the Sciences and the Humanities* (Cham: Springer, 2017).

61. See e.g. Lorraine Daston and H. Otto Sibum, 'Introduction: Scientific Personae and Their Histories', *Science in Context* 16, nos. 1–2 (2003): 1–8; David Aubin and Charlotte

has shown, for example, how scholars in the early modern period cultivated the habitus of an absentminded and emotionally detached scholar to free themselves from the obligations of family life.[62] For Pannekoek, the self-fashioning into two distinct identities can also be imagined an attempt to shield himself from the negative consequences of being a Marxist scientist or a bourgeois academic Marxist. By separating his Marxist activism from his scientific research, he intended to avoid astronomers seeing him as overtly political and socialists seeing his as elitist.[63]

On the other hand, personae have been constructed as exemplars of how scientists or scholars ought to act and behave and how they should produce their work. Scientific personae, thus conceptualized, embody constellations of virtues and skills that can be contrasted against other practitioners adhering to competing virtues.[64] Consequently, as Herman Paul argues: 'Scholarly personae tend to remain invisible to researchers who focus exclusively on individual practitioners, without comparing their models of scholarly selfhood to those of practitioners committed to different constellations of goods.'[65] In the case of Albert Einstein, for example, his moralized conception of what it means to be a proper theorist becomes especially visible in his opposition to the convictions of the majority of his colleagues. As Jeroen van Dongen has shown, Einstein was well aware of his status as an exemplar in physics and beyond, and he actively used his status to influence the direction of theoretical physics.

Bigg, 'Neither Genius nor Context Incarnate: Norman Lockyer, Jules Janssen and the Astrophysical Self', in *The History and Poetics of Scientific Biography*, ed. Thomas Söderqvist (Aldershot: Ashgate, 2007); Gadi Algazi, 'Exemplum and Wundertier: Three Concepts of the Scholarly Persona', *BMGN — Low Countries Historical Review* 131, no. 4 (2016): 8–32; Herman Paul, 'German Thoroughness in Baltimore: Epistemic Virtues and National Stereotypes', *History of Humanities* 3, no. 2 (2018): 327–350; Lea Beiermann and Elisabeth Wesseling, 'Physiology and Philhellenism in the Late Nineteenth Century: The Self-Fashioning of Emil du Bois-Reymond', *Science in Context* 33, no. 1 (2020): 19–35.

62. Gadi Algazi, 'Scholars in Households: Refiguring the Learned Habitus, 1480–1550', *Science in Context* 16, nos. 1–2 (2003): 9–42.

63. As we have seen, this was not always successful as his political beliefs at times hindered his astronomical career. Conversely, Pannekoek's academic career was a vulnerable point of attack for his socialist critics. Communist activist Karl Radek called him an 'astronomer gazing only at the stars, and never at a living worker' after Pannekoek had criticized the direction of the Bolshevik Revolution. Quoted in Voerman, 'Principled Theorist', 68.

64. Paul, 'What Is a Scholarly Persona?', 362–363; Paul, 'The Virtues and Vices of Albert Naudé: Toward a History of Scholarly Personae', *History of Humanities* 1, no. 2 (2016): 327–338.

65. Paul, 'What Is a Scholarly Persona?', 364.

Crucially, he altered his recollection of his path to the general theory of relativity, the most important of his achievements, to reflect less how the theory was actually developed and more how the older Einstein believed theoretical physics should be conducted. Einstein re-imagined his past self in his recollections with the goal of changing the direction of theoretical physics research to find acceptance for his controversial new standards and virtues for the discipline.[66]

While studies on personae and epistemic virtues have often focused on specific disciplines or time periods, they also enable broader perspectives on how ideals in science shift over longer time periods.[67] One of the most prominent examples is Lorraine Daston and Peter Galison's seminal book *Objectivity*, which traces the development of various interpretations of objectivity as epistemic virtues. In particular, they argue that mechanical objectivity emerged as an epistemic virtue in the mid-nineteenth century as a reaction to the then-dominant epistemic virtue of truth-to-nature, which emphasized reason and active imagination to find universal truths hidden behind the appearance of nature. Steadily, this ideal was replaced by one where scientists were expected to operate in a machine-like manner to avoid the influence of their own subjectivity and to let nature speak for itself. This was the virtue of mechanical objectivity. Mechanical objectivity itself was supplanted as the dominant virtue in the early twentieth century by judgemental objectivity, or trained judgement, which called upon educated professionals to use their trained perception and intuition to search for structure and family resemblances in natural phenomena.[68]

According to Daston and Galison, epistemic virtues are closely tied to specific conceptions of selfhood and expressed in ways to discipline the self — to counteract its perceived weaknesses and emphasize its strengths. Mechanical objectivity, for example, was linked to a conception of the self that was active and always imposed its subjectivity on observations. This active self should be tamed by using mechanical techniques of representation and self-restraint. Truth-to-nature, on the other hand, was connected to the idea of a fragmented self wherein the human mind was seen as a

66. Jeroen van Dongen, 'The Epistemic Virtues of the Virtuous Theorist: On Albert Einstein and his Autobiography', in Van Dongen and Paul, *Epistemic Virtues*.

67. See e.g. Steven Shapin, *The Scientific Life: A Moral History of a Late Modern Vocation* (Chicago: University of Chicago Press, 2008), for the development of the scientific persona in the modern period.

68. Lorraine Daston and Peter Galison, *Objectivity* (New York: Zone Books, 2007); Peter Galison, *The Objective Image* (Utrecht: Universiteit Utrecht, Faculteit Geesteswetenschappen, 2010).

collection of faculties. To achieve truthfulness, scholars needed to use the faculties of reason and active imagination, while shutting out faculty of the passive imagination, which could lead to delusions and fanaticism.[69] The interconnectedness of epistemic virtues and conceptions of the self make it a very promising perspective for investigating Pannekoek. In his astronomical work, Pannekoek paid much attention to the psychology and physiology of human sight and how this influenced observations of the stars and the Milky Way. This built upon an earlier tradition of scientists in the nineteenth century who became increasingly interested in the relation between human perception and scientific observation.[70] In many cases, they actively used the act of observation to study their own psychology and physiology, in what Jutta Schickore has termed the 'reflexive turn' in science.[71] Likewise, in his Marxist writings, Pannekoek extensively elaborated on the role of the human mind in dialectic materialism — an aspect that he felt was lacking in the writings of Marx and Engels. Many of his philosophical articles discussed how the human mind processed information and how it turned experience into general abstractions. These concerns make him an ideal subject to study how epistemic virtues are cultivated as technologies of the self.

The possibility of relating Pannekoek's Marxist philosophy to his epistemic virtues in astronomy illustrate the potential merit of using this his-

69. Lorraine Daston and Peter Galison, 'The Image of Objectivity', *Representations* 40 (1992): 81–128; Lorraine Daston, 'Objectivity and the Escape from Perspective', *Social Studies of Science* 22, no. 4 (1992): 597–618; Daston, 'Fear and Loathing of the Imagination in Science', *Daedalus* 127, no. 1 (1998): 73–95; Peter Galison, 'Image of Self', in *Things That Talk: Object Lessons from Art and Science*, ed. Lorraine Daston (New York: Zone Books, 2004); Daston and Galison, *Objectivity*.

70. See e.g. Jimena Canales, 'Exit the Frog, Enter the Human: Physiology and Experimental Psychology in Nineteenth-Century Astronomy', *British Journal for the History of Science* 34, no. 2 (2001): 173–197; Canales, 'Sensational Differences: The Case of the Transit of Venus', *Cahiers François Viète* 1, nos. 11–12 (2006): 15–40; Klaus B. Staubermann, 'Investigating Vision and the Reversion Spectroscope: Early Astronomical Colour Studies in Experimental Psychology', *Nuncius* 18, no. 2 (2003): 755–764; Christoph Hoffmann, 'Constant Differences: Friedrich Wilhelm Bessel, the Concept of the Observer in Early Nineteenth-Century Practical Astronomy and the History of the Personal Equation', *British Journal for the History of Science* 40, no. 3 (2007): 333–365; Alexandra Hui, *The Psychophysical Ear: Musical Experiments, Experimental Sounds, 1840–1910* (Cambridge, MA: MIT Press, 2013); Julia Kursell, '"False Relations": Hermann von Helmholtz's Study of Music and the Delineation of Nineteenth-Century Physiology', *Nineteenth-Century Music Review*, 2020, 1–22, 13–20.

71. Jutta Schickore, *The Microscope and the Eye: A History of Reflections, 1740–1870* (Chicago: University of Chicago Press, 2007).

toriographical tool. But there are also other reasons to believe that a focus on epistemic virtues and scientific personae is fruitful when attempting to connect different aspects of a researcher's biography. Matthew Stanley, for example, has shown how in the case of the Quaker and astronomer Arthur Eddington, many of his scientific virtues could be traced back to his religious Quaker values. Stanley termed these 'valence values' in analogy to valence electrons in chemistry, which 'facilitate bonding through their ability to be, in a sense, shared between atoms. Similarly, I am interested in those values that facilitate interaction between science and culture.'[72] My approach will be slightly different. Instead of establishing virtues that crossed domains, I wish to argue that Pannekoek's epistemic virtues in both Marxism and astronomy are connected precisely because they both emerged from a single conception of the self. At the same time, there can also be a tension between the idealizations captured by the scientific persona and the realities scientists faced in practice. In these situations, a focus on epistemic virtues and the scientific personae can illuminate how scientists navigated such contradictions by crafting a self-image that befitted their unique situation.[73]

Pannekoek himself rarely discussed what he considered a virtuous approach to astronomy or how he envisioned an ideal scientist, but the contours of his epistemic virtues and persona are revealed in other ways. One way of uncovering his epistemic virtues is by analysing how he discussed his scientific practice. It is important to note that how he articulated his approach to science does not necessarily concur with what he actually did. As Schickore reminds us: 'Historians have long warned that the study of scientific publications alone cannot give us an adequate picture of the activities involved in scientific research. Experimental reports are not a reliable source of information about what researchers really do in the laboratory.'[74] Scientific publications do not show what has actually

72. Matthew Stanley, *Practical Mystic: Religion, Science, and A. S. Eddington* (Chicago: University of Chicago Press, 2007), 6. In his book, Stanley uses the term values, but in a chapter published in 2017, he uses the term epistemic virtues for the same characteristics. See Matthew Stanley, 'Religious and Scientific Virtues: Maxwell, Eddington, and Persistence', in Van Dongen and Paul, *Epistemic Virtues.*

73. See e.g. Abha Sur, *Dispersed Radiance: Caste, Gender, and Modern Science in India* (New Delhi: Navayana, 2011); Jessica Wang, 'Physics, Emotion, and the Scientific Self: Merle Tuve's Cold War', *Historical Studies in the Natural Sciences* 42, no. 5 (2012): 341–388; Wang, '"Broken Symmetry": Physics, Aesthetics, and Moral Virtue in Nuclear Age America', in Van Dongen and Paul, *Epistemic Virtues.*

74. Jutta Schickore, *About Method: Experimenters, Snake Venom, and the History of Writing*

happened, but rather what scientists consider the most important aspects of their research. As a result, they are excellent sources to find out what researchers think ought to be done. In this way, the methodological sections of experimental reports have been examined by Schickore, who argues that: 'method-related concepts, statements, and reflections as they are presented in experimental reports are significant because they reflect the author's understanding of the structure and organization of good experimental research.'[75] Similarly, Daston and Galison have shown that the introductions of scientific visual compendia were a place where epistemological battles could be fought and where scientists could explicate what it meant to have a 'scientific eye'.[76]

The fact that Daston and Galison focused their attention on visual compendia points toward another avenue way to investigate Pannekoek's epistemic virtues: by focusing on the visual and aesthetic aspect of his astronomical research, we can explore his ideas on scientific observation and representation. For a long time, historians and philosophers of science had dismissed images as subsidiary tools intended to supplement knowledge that was mainly conveyed in words and equations. Similarly, they have traditionally treated observation as a passive process that was subservient to the construction of scientific theories and empirical laws. An increased interest in the visual aspect of science in the last few decades, however, has made it clear that scientific images are worth studying in their own right when trying to understand how science is practised.[77] The aesthetic and technical choices scientists make in producing and reproducing images do not just reveal aspects of the knowledge that they wish to convey; they also reflect how scientists believe nature should be observed and which skills and epistemic virtues are required for this.[78] This is certainly true for Pannekoek's research on the visual appearance of the Milky Way, in

Scientifically (Chicago: University of Chicago Press, 2017), 5.

75. Schickore, *About Method*, 5.

76. Daston and Galison, *Objectivity*, 19–27.

77. For an overview of how historians started to research scientific images, see Alex Soojung-Kim Pang, 'Visual Representation and Post-Constructivist History of Science', *Historical Studies in the Physical and Biological Sciences* 28, no. 1 (1997): 139–171; Caroline A. Jones and Peter Galison, eds., *Picturing Science, Producing Art* (New York: Routledge, 1998); Sachiko Kusukawa, 'Classics from This Journal: Martin Rudwick's "The Emergence of a Visual Language for Geological Science, 1760–1840"', *History of Science* 54, no. 1 (2016): 98–104.

78. See e.g. Daston and Galison, 'Image of Objectivity'; *Objectivity*; Mary G. Winkler and Albert van Helden, 'Representing the Heavens: Galileo and Visual Astronomy', *Isis* 83, no. 2 (1992): 195–217; Simon Schaffer, 'On Astronomical Drawing', in *Picturing Science,*

which he was explicit about how human perception worked, what this meant for how the Milky Way should be observed, and the results of this research could best be represented in scientific publications.

Finally, we can investigate Pannekoek's epistemic virtues through his assessment of other scientists. By looking at how he reacted to the work of contemporary astronomers, what he perceived to be their flaws, and how he suggested these could be corrected, we gain valuable insight into what he did and did not consider proper scientific conduct. Alternatively, we can also investigate how he described the contributions and virtues of other astronomers in his historical and biographical work. In such descriptions, the ideals of the author often shine through. As historians of science have shown, biographers can sculpt their biographical subjects into an exemplar of scientific behaviour by emphasizing certain virtues and practices.[79] Thus, Pannekoek's historical writings, in particular, are valuable sources that will help us to further clarify his epistemic virtues and ideal scientific persona.

Scope and Structure

The following three chapters will provide a close analysis of Pannekoek's astronomical research, with each chapter focusing on a different area of research. Throughout each chapter, there are three recurring historiographical themes: how did astrophotography impact Pannekoek's astronomical research; what we can learn by investigating his epistemic virtues and scientific persona; and what relations existed between his astronomy and Marxism.

Producing Art, ed. Caroline A. Jones and Peter Galison (New York: Routledge, 1998); Lorraine Daston, 'On Scientific Observation', *Isis* 99, no. 1 (2008): 97–110; Lorraine Daston and Elizabeth Lunbeck, 'Introduction: Observation Observed', in *Histories of Scientific Observation*, ed. Lorraine Daston and Elizabeth Lunbeck (Chicago: University of Chicago Press, 2011); Nasim, *Observing by Hand*; Chunglin Kwa, 'The Visual Grasp of the Fragmented Landscape: Plant Geographers vs. Plant Sociologists', *Historical Studies in the Natural Sciences* 48, no. 2 (2018): 180–222.

79. See e.g. Rebekah Higgitt, 'Discriminating Days? Partiality and Impartiality in Nineteenth-Century Biographies of Newton', in *The History and Poetics of Scientific Biography*, ed. Thomas Söderqvist (Aldershot: Ashgate, 2007); Helge Kragh, 'Received Wisdom in Biography: Tycho Biographies from Gassendi to Christianson', in *The History and Poetics of Scientific Biography*, ed. Thomas Söderqvist (Aldershot: Ashgate, 2007); Janet Browne, 'Making Darwin: Biography and the Changing Representations of Charles Darwin', *Journal of Interdisciplinary History* 40, no. 3 (2010): 347–373; Daston and Galison, *Objectivity*, 216–251; Saarloos, 'Virtue and Vice'.

The first chapter will focus on Pannekoek's efforts to depict the visual appearance of the Milky Way, for which he employed both visual and photographic techniques. In this research, Pannekoek elaborated extensively on his ideas of human perception and how this was altered by prior experience. He also developed photographic techniques to mimic the workings of the human eye freed from the influence of personal subjectivity. To fully appreciate his epistemic virtues in observing and representing the Milky Way, we must also explore his philosophy of mind.

The second chapter will discuss Pannekoek's statistical astronomy, his contributions to the debates on the size and structure of the galactic system, and his unsuccessful attempt to develop a photographic method to determine stellar statistics. A notable difference between his approach and that of his contemporaries was how he investigated the statistical distribution of stars. Rather than relying on standardized methods to order this distribution, he emphasized the importance of using judgement to find stellar clusters. This led him to significantly different results despite relying on the same published catalogues. Both in the way that Pannekoek approached statistical astronomy and in the resulting models of the galactic system, there are clear analogies with his Marxist writings.

The final chapter provides an analysis of Pannekoek's theoretical and observational contributions to astrophysics. One of the reasons why Pannekoek switched to astrophysics was because he believed it was eminently suited to benefit society. But as an astronomer without an observatory, he had to rely on photographic plates borrowed from other observatories for his observational research, which severely limited his possibilities. Therefore, he fashioned his methodology and his persona in such a way that he could manage the constraints of his institutional circumstances while following his conviction that scientific progress should lead to societal progress.

Together, these three chapters provide a thorough investigation of Pannekoek's contributions to astronomy and their relation to both his own Marxist philosophy and the historical development of science in the first half of the twentieth century. In doing so, they not only provide a clear image of Pannekoek as a unified person, but also help us to understand the relation between science and political philosophy, and clarify what it means to a scientist.