MAKING SCIENCE THROUGH "MENTAL INSPECTION": ON WILLIAM HERSCHEL'S MANUSCRIPT "KANT (NOTES ON PHILOSOPHY)"

ABSTRACT

This paper discusses some aspects of William Herschel's manuscript "Kant (notes on philosophy)," which is stored at the Harry Ransom Center (The University of Texas at Austin). The manuscript, which is published for the first time as an appendix to the present article, is a commentary on the first sections of the German second edition of the *Critique of Pure Reason*, and represents the evidence that William Herschel was familiar with Kant's philosophy in the 1790s.

KEYWORDS: W. Herschel; I. Kant; mental inspection; intuition; radiant heat.

1. HERSCHEL'S NOTES ON KANT'S PHILOSOPHY

Seeking to frame Kant's writings within the scientific debates of the 1750s onward, Kant studies on both the pre-critical and critical period have offered a number of different assessments of the influence of eighteenth-century natural scientists on his philosophy.[1] However, we still lack an enriched picture of Kant's own influence on late-eighteenth-century natural scientists and their immediate successors, and achieving such a picture presents difficulties.[2] The present paper aims at contributing to this field, by showing that William Herschel became acquainted with Kant's philosophy in order to tackle certain conceptual problems arising from his experiments on radiant heat in 1800. The names of Immanuel Kant and William Herschel were first publicly associated in 1791, on the occasion of the publication of an excerpt of Kant's *Universal Natural History and Theory of the Heavens* as an appendix to the German edition of Herschel's writings published under the title *Über den Bau des Himmels*.[3] In 1792, Herschel's and Kant's works were described by Johann Elert Bode as a "felicitous example of the agreement between experience and theory, empirical observations and speculative reason" (Bode 1792, p. 590n, my translation).[4] Kant and

[1] Studies on Kant and the sciences of his time have been proposed by Buchdahl (1969), Friedman (1992), Lefevre and Wunderlich (2000, 2001), Schönfeld (2000), Watkins (2001). For a study on Kant's theory of aether and a comparison with Euler, see also Förster (2000). Grillenzoni (1998) covers in detail only the first pre-critical writings until 1755.

[2] The collection by Friedman and Nordmann (2006) presents a selection of relevant aspects of Kant's work on natural science and the philosophy of science that influenced nineteenth-century scientists and mathematicians. However, the book does not take into account the influence that Kant's philosophy exerted on scientists, such as William Herschel and Johann Elert Bode, who were his contemporaries, or on Kant's immediate successors in both Prussia and Great Britain. For Kant's view of chemistry and its legacy, see also Carrier (1990).

[3] The collected works of William Herschel which appeared in the English edition of *On the Construction of the Heavens* were the following: *Account of some Observations tending to investigate the Construction of the Heavens*, *On the Construction of the Heavens*, and *Catalogue of a second Thousand of new Nebulae and Clusters of Stars; with a few introductory Remarks on the Construction of the Heavens*.

[4] For a scientific biography of Bode, see Schwemin (2006). In the 1790s Bode was a major actor in creating a unified picture of Kant and Herschel's works. It was in his *Astronomisches Jahrbuch* that Kant and Herschel could indirectly

Herschel never met in person nor had a correspondence; however, they were interested in each other's work. Kant, for instance, read Herschel's papers and acknowledged his great contribution to astronomy in a number of places, including in the 1791 excerpt of his cosmology. Yet the literature has never shown to what extent Kant, conversely, exerted an influence on Herschel, and the present paper aims at filling this gap.

In what follows, I shall show that Herschel was acquainted with Kant's work and that some specific features of transcendental philosophy attracted him. In recent years, Michael Hoskin has done excellent biographic work on both William and Caroline Herschel and we have now a rich historical picture in which their scientific work can be framed.[5] However, as mentioned above, there is still a gap to be filled concerning Herschel's philosophical readings and on how they eventually influenced his research. In the Appendix to the present paper, the reader will find the typescript of the original manuscript containing William Herschel's notes on the *Critique of Pure Reason*. This document, entitled "Kant (notes on philosophy)," is stored at the Harry Ransom Center (The University of Texas at Austin) and shows that Herschel read at least the *Transcendental Aesthetic* of the second German edition of Kant's *Critique* published in 1787. The manuscript is undated, but for reasons that I spell out in the following sections, it is plausible to date it after 1791 and before September 1800.

What should attract our attention, however, is not only the fact that Herschel read Kant and was familiar with his philosophy, but also that Herschel was thinking about some specific aspects of Kant's metaphysics. It is worth investigating which aspects of Kant's metaphysics were of interest for Herschel and why this was the case. I suggest, indeed, that there was a compelling reason for Herschel to become interested in transcendental philosophy in the 1790s, and that it had to do with Kant's doctrine of intuition. To this speculative interest, one should add that in 1800 Herschel faced a dilemma arising from his experiments on light and heat, originating from a conflict between an incomplete concept of the nature of radiation and the lack of a coherent theory of perception.[6] In what follows, I first identify the crucial elements of Kant's work that attracted Herschel's attention, such as the notion of intuition, and then analyse Herschel's manuscript and his correspondence in

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communicate, through brief review letters, and astronomers could see to what extent their views of the universe were harmonised. In 1794 Bode published his correspondence with Kant together with comments on Herschel's works and linked their names in dealing with cosmology and the major astronomical discoveries of the eighteenth century.

[5] For a biography of William Herschel and his view of astronomy and cosmology, see Hoskin (2012). For a comparison between Kant and Herschel's cosmology, see Schaffer (1978, 1980). For a more recent scientific biography of William and John Herschel, see Cunningham (2018). For a study on Herschel's education, see Winterburn (2014).

[6] For an account of the dilemma, see Lovell (1968) and Chang and Leonelli (2005a, 2005b). The dilemma Herschel faced in 1800 concerned the relationship between radiant heat and light, their properties and modes of propagation, and has been an object of enquiry by historians of science, such as Hilbert (1999). More recently, Chang and Leonelli (2005a, 2005b) have framed Herschel's experiments within the debates on the ontology of radiation in the nineteenth-century history of science and developed a philosophical interpretation of them as "unified and pluralistic theories of radiation".

order to show that in 1800 Herschel deepened his knowledge of Kant's philosophy in order to reflect upon the method used in his own experiments on radiant heat.

2. HERSCHEL'S INTEREST IN THEORIES OF PERCEPTION AND INTUITION

William Herschel's manuscript "Kant (notes on philosophy)" refers to the pagination of the second German edition of the *Critique of Pure Reason* (1787) of which he summarised the first sections. His reflections focus on the *Transcendental Aesthetic* and on the role of intuition. We also find several notes on the nature of synthetic *a priori* judgements. Herschel probably became acquainted with Kant's works after the publication of the excerpt of Kant's cosmology in 1791, and through the letters that Bode published in 1794 devoted to the comparison of his system with Kant's (see Bode 1792 and 1794). In the early 1780s Herschel was acquainted with the works of Newton, Priestley, Boscovich and Michell and had a fair knowledge of Locke, Descartes and Huygens. His studies in philosophy were encouraged by his father, and Herschel's interest in philosophy and metaphysics is manifest throughout his entire career.[7] In particular, he was interested in exploring the interplay of philosophy and scientific observation, as emerges from "On the utility of speculative enquiries," presented at the Philosophical Society of Bath in 1780. In it, Herschel defended the role of metaphysics as the most elevated part of physics:

> It was said that speculation and metaphysics were of little use to mankind. This I deny. The perfection of our nature is evidently to be looked for in the superior powers of reason and speculation. What would all experiments avail if we should stop there, and not argue upon them so as to draw general conclusions? And how can we argue and draw conclusions if the superior intellectual powers are not improved by frequent exercise in speculative researches? (Herschel 1780a, p. lxxxii)

Herschel thus considered metaphysics as a fundamental aspect of his investigations, which could have nurtured his capacity for generalising scientific results. In the paper entitled "On the existence of space," for instance, Herschel advanced an alternative view to Locke's theory of knowledge in order to prove the existence of space.[8] After recalling that for Locke knowledge consists in the

[7] According to Macpherson (1919, p. 9), William Herschel's sister Caroline reported that: "My brothers were often introduced as solo performers and assistants in the orchestra of the court, and I remember that I was frequently prevented from going to sleep by the lively criticism on music on coming home from a concert, or conversations on philosophical subjects which lasted frequently till morning […]. Generally their conversation would branch out on philosophical subjects, when my brother William and my father often argued with such warmth that my mother's interference became necessary when the names Leibnitz, Newton, and Euler sounded rather too loud for the repose of her little ones, who ought to be in school by seven in the morning".

[8] A number of the philosophical manuscripts collected in Dreyer's edition of Herschel's scientific works reveal that Herschel commented on Locke's *An Essay Concerning Human Understanding*. References to Locke's work concern Book III, Chapters 9 and 10, devoted to the imperfection of words. Other references appear to Book III, Chapter 4,

agreement or disagreement of our perception with our Ideas, and that perception can be obtained by intuition, by demonstration and by sensation, Herschel draws a distinction between the perception obtained by intuition and perception obtained by consciousness. The latter is absent in Locke's system, yet Herschel maintains that it is by consciousness that we perceive our existence. In Herschel's view, "our ideas of things that exist have any other connection with existence than by consciousness; therefore, all proofs relative to existence must be taken from that principle" (1912, p. lxxxvii). When we perceive by intuition we have two ideas in our mind and we perceive their agreement or disagreement. But when we perceive by consciousness we have a single perception "which is less compounded than in intuition because it does not require two ideas as it happens for intuition" (ibid.). Herschel emphasised the difference between his own view and Locke's: according to the latter, we perceive our own existence through intuition, by reflecting upon the terms *I am*; in Herschel's view, however, the knowledge of my own existence occurs by means of consciousness only, and the very word *I* means something that exists, and *am* is nothing else but a repetition of the same idea. Furthermore, that *I* exist is immediately evident to consciousness and is not communicable in the manner of intuition and demonstration: "that *I am* is very evident to me because *I* perceive it by consciousness" (p. lxxxv).

This argument is extremely helpful in clarifying why, in reading the *Critique of Pure Reason*, Herschel translated intuition (*Anschauung*) with the expression "mental inspection," thereby revealing his attempt to interpret Kant's philosophy on the ground of his conjecture about existence and perception through consciousness, while at the same time adopting Locke's terminology:

"33. Mental inspection. Intuition. Anschauung.

This requires objects. The mind must be acted upon, affected. The capacity we have of being thus acted upon is that of sensation (or receptivity). Only this can give us what is necessary for mental inspection. But the understanding thinks upon them and hence springs up conceptions or ideas

33. All thinking must in the end relate to an inspection of objects furnished by sensation

34. The effect of objects upon the imagination (*Vorstellungsfähigkeit*) is sensation. The mental inspection of the sensation is experience. The unknown object which causes it, is, in the mind, an <u>appearance</u>.

This may be called the <u>matter</u>. The <u>form</u> of it is what remains in the mind. This may be produced a priori in the mind independent of all actual sensation" (Herschel N.d.).

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devoted to the imperfection of language. Whereas Locke never used the concept of "inspection" and did not offer a definition of intuition (see Locke 1975, Book III, Chapter 2) similar to Herschel's, he differentiated a "mental" from a "verbal" use of words and discussed how the mental use can become verbal (Book III, Chapter 5). All this corroborates the idea that Herschel's view of intuition, despite being different from Locke's, was yet defined by means of some of Locke's notions, such as that of the mental use of words, thereby informing Herschel's reflections on the notion of intuition as "mental inspection".

Herschel saw a possible correspondence between his notion of "perception through consciousness" and Kantian intuition, but he wanted to carry out his interpretation using Locke's terminology. According to Locke, the "mental," contrary to the "verbal," is something that does not involve the use of words, and indeed for Kant intuitions were devoid of conceptual content, they were immediate singular representations (see KrV B41). Despite Herschel's criticism of Locke's theory of perception and intuition, we find him in the 1780s trying to propose a scientific methodology compatible with Locke's philosophy which did not use the expression "mental inspection."

In 1787 Herschel published "An account of three volcanos in the Moon" in the *Philosophical Transactions of the Royal Society of London*. In it, we again find an example of his willingness to explore the interplay of philosophical reflection and scientific observation. Herschel assigned a specific role to the use of analogy and to the "eye of reason" in astronomical observation. According to him, "the phenomena of nature, especially those that fall under the inspection of the astronomer, are to be viewed, not only with the usual attention to facts as they occur, but with the eye of reason and experience" (Herschel 1787, p. 229).

Herschel's expressions the "eye of reason" and "experience" characterise scientific methodology in such a way that observation alone is not sufficient to grasp astronomical phenomena, and the natural philosopher must employ other tools such as analogy and experiment. From the passage above, it emerges that an enquiry concerning the generalisation of phenomena and their unification necessarily constitutes a part of the scientific methodology, conjointly with observations and experiments. Thus, Herschel believed that sensation (to which observation belonged) and analogical reasoning played different roles in the interpretation of experimental results.[9] Herschel felt, however, that Locke's account of perception by sensation was insufficient. What, indeed, could have corresponded to "the eye of reason" in Locke's philosophy? Furthermore, in the face of the 1800 experiments on radiant heat, Herschel also had to abandon the idea that through analogy the eye of reason could 'see' behind mere observation in such a way that it would lead to consistent results. He therefore had to look for a new scientific methodology in dealing with radiation. This dissatisfaction probably constituted one of the most important factors that drove Herschel's increasing interest in Kant's transcendental philosophy and in his account of intuition as a source of immediate non-conceptual certainty.[10]

[9] As highlighted in the next sections, this distinction will play an important role for the interpretation of his experimental results on light and radiant heat in 1800.

[10] It is worth mentioning that in the *Memorandum of the Defect of Language*, Herschel talked about "intellectual inspection" and its connection to perception and reflection (Herschel N.d (in his 1912, pp. cxvii–cxix)). He discussed the relevance of "mental inspection" with respect to mathematical and geometrical construction and used it in order to distinguish the notion of real space from that of ideal space. In Herschel's view, ideal space is something springing out of the mind and is produced by intellectual inspection. Herschel's *Memorandum*, which refers to Locke's *Essay*, does

3. HERSCHEL'S "MENTAL INSPECTION" IN MAKING SCIENCE

Herschel published a series of articles in the *Philosophical Transactions* devoted to exploring the methodology and the results of the experiments he had performed in order to study the propagation of solar light and heat.[11] These contributions were entitled "Investigation of the powers of the prismatic colours to heat and illuminate objects" (1800a), "Experiments of the refrangibility of the invisible rays of the sun" (1800b), and "Experiments on the solar and on the terrestrial rays that occasion heat" part I (1800c) and part II (1800d). In 1800 Herschel interpreted radiant heat as "invisible light," namely he associated a *momentum* to the solar rays that is "unfit for vision." Yet even if invisible light is not perceived by sight, it can be still indirectly determined by measuring heat produced in the red part of the spectrum. The theoretical implication that there is "invisible light," an unobservable *par excellence*, opened the question of how its action can be measured directly or indirectly and the role of perception in this procedure.[12] After repeated examination of several objects with a microscope, Herschel concluded that there must have been an alternative source of radiation from the sun. In other words, he assumed that this source of radiation was distinct from that of light and was responsible for the heat that the selected thermometer detected:

> In this case, radiant heat will at least partly, if not chiefly, consist, if I may be permitted the expression, of invisible light; that is to say, of rays coming from the sun, that have such a momentum as to be unfit for vision. And, admitting, as is highly probable, that the organs of sight are only adapted to receive impressions from particles of a certain momentum, it explains why the maximum of illumination should be in the middle of the refrangible rays; as those which have greater or less *momenta*, are likely to become equally unfit for impressions of sight. Whereas, in radiant heat, there may be no such limitation to the momentum of its particles. (Herschel 1800a, pp. 272–273)

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not mention Kant and therefore we can suppose that the manuscript published in the Appendix to the present paper was written afterwards.

[11] Du Châtelet (1739) proposed a series of experiments to determine whether primitive rays of different colours had different degrees of heat. The subsequent experiments of Landriani, Rochon, and Herschel not only gave a complete solution to this question, but also led to new and important results (Fauque 1985, pp. 23–35). Kant and Herschel were interested in exploring the possible common cause for phenomena of light and heat, in other words they were testing the same possibility from different perspectives: the existence of the aether or a common substrate whose ponderable effects were light and heat. Herschel did not embrace any definite solution; he rather endorsed a suspension of judgment concerning the possible common cause of heat and light. Kant, on the other hand, pursued his programme aiming at explaining "all varieties of matter" by combining the original forces of attraction and repulsion with which the aether is endowed in the *Transition from the Metaphysical Foundations of Natural Science to Physics* collected in the *Opus postumum* (Onnasch 2009).

[12] More specifically, the question of invisible light led Herschel to study imponderables. For a detailed description of the goals of natural scientists working on this topic, see Heilbron (1993).

As Chang and Leonelli (2005a, 2005b) underlined, however, Herschel changed his mind in his third paper, "Experiments on the solar and on the terrestrial rays that occasion heat, part I" (1800c). In the first two papers ("Investigation of the powers of the prismatic colours to heat and illuminate objects," "Experiments of the refrangibility of the invisible rays of the sun"), Herschel tried to build up a unitary picture in which the same agent caused these varying lighting and heating effects as its refrangibility gradually increased. In "Experiments on the solar and on the terrestrial rays that occasion heat, part II," Herschel did not deny the possibility of finding a common cause for explaining light and heat with respect to our organs of senses, but he could not provide a good argument for it:

> It does not appear that nature is in the habit of using one and the same mechanism with any 2 of our senses; witness the vibration of air that makes sound; the effluvia that occasion smells; the particles that produce taste; the resistance or repulsive powers that affect the touch; all these are evidently suited to their respective organs of sense. It was possible that vision and the sense of heat provide an exception here by sharing the same cause, but the *onus probandi* ought to lie with those who are willing to establish such a hypothesis. (Herschel 1800d, p. 507)

Herschel thus supported the hypothesis that light and heat could be unified under the same laws, and that one could produce a geometrical construction of the *continuum* space in which the trajectories of particles develop their own dynamics, thereby producing deviations and various degrees of scattering. This option could have provided the possibility of reconciling the corpuscular and wave theories of light with the observation of radiant heat.[13]

Nevertheless, Herschel could not solve this problem, and apparently gave up the idea of unifying light and radiant heat. He embraced a view according to which caloric rays were the direct cause of heating, and light rays were the direct cause of illumination. Thus, on the one hand, Herschel decided to follow his metaphysical belief, according to which the fact that consciousness can be connected to the existence of heat must be the ground for the proof of the existence of radiant heat. On the other hand, Herschel was forced to adopt the separation between light and heat radiation, because neither direct observation nor analogical reasoning (i.e. the "eye of reason") could provide an element in favour of the contrary. Furthermore, one should notice that from Herschel's perspective the perception through consciousness of the existence of a common cause for radiant heat and light was not enough to unify the observed phenomena. As he came to understand the limits of his own speculations, Herschel was attracted by Kant's transcendental philosophy and in

[13] For a study on the wave theory of light in the early 1800s, see Buchwald (1989).

particular by his doctrine of intuition. Herschel tried to show whether his experiment could have provided at least an intuition of invisible light, which can be measured only indirectly. Herschel thus directed his attention to Kant's doctrine of intuition, or as he called it of "mental inspection," because he wanted to provide a justification for the unification of light and heat radiation. That Herschel was indeed working on Kant's metaphysics is revealed in a letter to Herschel dated 9 September 1800, from William Watson Jr.[14]

My dear friend, I have lately perused in Nicholson's last journal a paper of a Mr Leslie who controverts your experiments on heat and light and particularly denies the existence of the invisible heating rays of the sun. It is written in a petulant style and I trust will be found as void of truth as it is of candour. He says that upon trying with an instrument of his own invention which he calls a photometer he could find no heat beyond the red rays of the spectrum of a prism, when it was so placed as to receive no heat from the vicinity of other objects, and attributes the heat you found to that proceeding from the paper and board the thermometer rested upon. This position I think will be deemed groundless to whoever considers the circumstances of your experiment […] if you should (think of using his photometer) it is to be had at Cary's, Optician in the strand […] When shall I have the happiness of seeing you at Bath? I need not tell you how much I wish for such an event. We will then converse on these matters and also on Kant's metaphysics. I wish to know how far you have proceeded in your examination of his philosophy. I doubt, tho' we begin upon the same grounds and proceed together some way, I shall be obliged to leave him, as I suspect him to make some portion of our knowledge to proceed from sources I cannot admit. (Lubbock 1933, pp. 280–281)

There is thus no doubt that Herschel's interest in Kant's philosophy increased when he came to interpret the results of the experiments on radiant heat. In this respect, Lovell's claim that Herschel lacked a coherent theory of perception can be developed by investigating Herschel's view of intuition and consciousness after 1800. Indeed, the inadequacy of Herschel's view of perception for interpreting data led him to become more and more familiar with philosophical speculations.

4. In search of a metaphysics of light and radiant heat

We have seen how in investigating the metaphysical foundations of his theory of matter and light, Herschel's aim was to interpret the experimental results in order to unify the phenomena of heat and light under the same cause. Even if he failed in this attempt, given his endorsement of a corpuscular theory of matter and light, it is worth noting that he endorsed a suspension of judgment on this topic

[14] William Watson Jr., son of the English scientist William Watson (1715–1787), was a member of the Royal Society and a close friend of William Herschel. It was he who introduced Herschel to the Royal Society and helped him in interacting with the British scientific community (Lubbock 1933).

and simultaneously pursued his research in metaphysics. In "Experiments of the refrangibility of the invisible rays of the sun," Herschel writes:

To conclude, if we call light, those rays which illuminate objects, and radiant heat, those which heat bodies, it may be inquired, whether light be essentially different from radiant heat? In answer to which I would suggest, that we are not allowed, by the rules of philosophising, to admit two different causes to explain certain effects, if they may be accounted for by one. (Herschel 1800b, p. 291)

In this passage Herschel refers to Newton's *Regulae Philosophandi*: in particular, we find here a reference to the first rule ("No more causes of natural things should be admitted than are both true and sufficient to explain their phenomena") and the second ("The causes assigned to the natural effects of the same kind must be, so far as possible, the same"), both appearing at the beginning of book III of the third edition of the *Principia* (Newton 1999, pp. 794–795).[15] Herschel might have continued to think of light and (radiant) heat as separate forms of radiation without contradicting Newton's rules; however, he chose to regard them as two different effects of the same cause. Before writing his third article on radiant heat, Herschel suspends judgment on the mechanism enabling this separation; however, he leaves open the possibility of finding a common cause for the reception and sensations of light and heat. This position represents a mere suspension of judgment concerning the metaphysics of light and heat, and notably mirrors Herschel's acknowledgment of the undecidability of the question of the possible common source of the human receptive capacities of light and heat.

Herschel accepted that the possible common source of the human receptive capacities of light and heat could not be presented to the "eye of reason" through empirical intuition, nor could it be mathematically constructed. Only an indirect methodology based on technological devices, such as the interferometer, could have eventually detected this common source. Yet the assumption of the existence of a common cause responsible for light and heat was a matter of metaphysics for Herschel, not one related purely to observation and experiment.

Before concluding our analysis, it is worth mentioning a relevant factor that led Herschel to deepen his knowledge of Kant's philosophy in 1800. This factor is mentioned in Watson's letter quoted in Section 3, and involves the debate on the theory of radiative heat and colours, with reference to Count Rumford's experiments on the propagation of heat (Thompson 1792, 1797; Lubbock 1933, pp. 183ff.).[16]

[15] For an account and their history, see Ducheyne (2012, pp. 109ff.).

[16] For the relevance of Herschel's studies on radiative heat and colours and the connection with Count Rumford's experiments, see Lubbock (1933, pp. 265, 267).

Sir John Leslie, who worked together with Count Rumford on this topic,[17] claimed in his paper "Observations and experiments on light and heat" (Leslie 1800a) that Herschel had no experience in the field of light experiments. His criticism is even more severe in a later communication dated 17 November 1800 (Leslie 1800b). In it, Leslie argued that Herschel's experiments were unsuccessful, his method was dogmatic and his idea of associating properties to each ray of light corresponding to the seven colours was a metaphysical assumption with no scientific import.[18] What is even more interesting is that Herschel received Leslie's papers in two ways. The first paper that is mentioned in Watson's letter was not a concern for him and led him to examine Leslie's photometer (Lubbock 1933, p. 281), whereas the second paper was more problematic because it highlighted the weaknesses of Herschel's method. Leslie called on Herschel to solve the dilemma of the undecidability of the question of the common cause of the perceptibility of light and heat and the possible common cause of radiation of light and heat rays.[19] As shown in the previous section, in his first two papers Herschel carried out numerous experiments to prove that the rays which occasion heat were of the same nature whether they came from the sun or from terrestrial sources, obeying the same kind of laws of reflection, refraction and scattering. Thus, he conceived radiant heat as a unified entity encompassing both the terrestrial type and the solar type of radiation. He explained the fact that radiation had different types of effects according to its refrangibility by referring to its interactions with receptors.

Thus, in Herschel's view, a possible solution to the dilemma could have been that the heat and light emitted by the sun, despite their common source and similar mode of propagation (through rays), are also composed of particles that interact with each other in different ways, and affect our receptors (e.g. the eye) in different ways. The particles' mode of propagation is the same in principle, but in propagating they interact according to different laws of scattering. Herschel presents the dilemma and its solution as follows:

[17] For further details on his research on heat in relationship with Count Rumford's, see Olson (1970, 1971).

[18] In Leslie (1800b, p. 416) we read: "To the mystic number seven, the child of judicial astrology, the Doctor bows with reverence. Light not only consists in seven primitive rays, but each ray has seven properties; and so likewise corresponding have the 'rays of heat'. To muster up precisely those seven analogous properties, however, required some degree of management, since one of them is to inform us, that the rays of light and those of heat 'are liable to be scattered on rough surfaces'; an expression which, if it has any meaning at all, must denote irregular reflection, and therefore, to common apprehension at least, seems comprised under a former head. The parallel so nicely drawn between the visible and invisible rays, changes, in the last article, into a curious contrast, which asserts, in despite of vulgar prejudices, that Light may not give Heat, and that Heat may compose Light".

[19] That Herschel faced a question of undecidability on the cause of heat emerged from Nicholson's report of Herschel's paper: "Dr. Herschel has not thought fit to adopt any of these terms in his Memoir, but has chosen to treat of the rays that occasion heat; not meaning either to state that these rays are heat, or the manner in which they produce it. In his prefatory observations he also in effect remarks that his present research is confined to the agency of heat in its state of radiance; without entering into any considerations respecting the general nature of heat itself, whether it be matter or modification, or of radiance, whether it be the projection of particles, the undulation of a fluid, or any other habitude or thing" (Nicholson 1800, p. 360).

Hence, we may conclude, that as the same cause, when it acts upon the rays of heat and light, produces effects so very different, it can only be accounted for by admitting the rays themselves to be of a different nature, and therefore subject to a different law in being scattered. It has already been shewn, that the rays of heat are, upon an average, less refrangible than those of light; and now it appears that they are also, if I may introduce a convenient term, less scatterable. (Herschel 1800d, p. 523)

Heat, as distinguished from light, is therefore composed of particles that in oscillating and vibrating acquire a different dynamic, whose effects our eyes cannot directly perceive. The heat generated by the sun is therefore detached from its emission of light; there is another process of radiation behind it. Is the source that is responsible for radiant heat also the cause of another kind of radiation, such as the one explaining electricity and magnetism? Herschel could not answer this question, but he continued searching for an answer, as testified by his study "Observations tending to investigate the nature of the sun in order to find the cause of symptoms of its variable emission of light and heat" (1801). He was attracted by the study of a theory of affection and perception that could be compatible with experimental results, and he tried to connect them with metaphysical principles and speculations that, at least in 1800, were also inspired by Kant's philosophy.

5. Conclusion

This paper seeks to encourage further research on Herschel's philosophical readings, but also to stimulate the search for an understanding of the influence that Kant exerted on both eighteenth- and early-nineteenth-century scientists. In this article I have emphasised the pressing questions that led William Herschel to deepen his philosophical knowledge, and in particular of Kant's philosophy, when he could not support his hypothesis of the common source of radiant heat and light on the ground of analogy and experiments alone. Kant's theory of the distinction between perception and intuition could have been a candidate to support Herschel's method and his hypothesis of a common cause accounting for the different scattering of the particles radiating heat and light. I have also shown the relevance of Kant's notion of intuition for Herschel's speculations in order to reflect upon the notion of "mental inspection" as an alternative to Locke's theory of perception and intuition.

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APPENDIX

The following typescript is taken from the Herschel Family Papers, Series II Sir William Herschel, Subseries A. Works 1763–1816 and it is entitled "Kant (notes on philosophy)," 16 pages, undated (M1113). The original manuscript is stored at the Harry Ransom Center, the University of Texas at Austin, TX. With the exception of editor's interpolations, all text is reproduced exactly as in the MS, including underlining. Editor's interpolations are marked with square brackets, and unconventional spellings or errors in original text are marked with [*sic*].

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Kant. The pages are referred by the n°.

1. All our knowledge begins with experience.
1. But does not therefore arise only out of expe[rience]

it may be a compound of what we receive by impressions and of what our Understanding (excited by impressions) gives out from its own power.

2. Is there a knowledge that does not depend upon experience, and is perfectly free from all impressions of the senses? Let it be called a priori to distinguish it from the knowledge which is derived from experience and which may be called a posteriori.
3. Experience can only teach us that things are so and so, but not that they cannot be otherwise.
4. We have knowledge a priori, for instance "all changes must have a cause." and all mathematical truths.
5. The author mentions Hume

5. Even the possibility of experience proves knowledge a priori.

5.6 Take away all what you know of body by impressions
the colour, the hardness, the weight, the impenetrability there will remain the space while it, (after

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being intirely [*sic*] vanished) had occupied before; and this you cannot leave out.

6. Our knowledge extends to things of which we can have no experience

7. The question is how the understanding comes to this knowledge a priori, and how far we may trust to it.

8. Those things that are beyond experience cannot be contradicted by experience. We may go from proof to proof and nothing but evident contradiction can stop us.

9.10 In reflecting upon the ideas we have received, new knowledge springs up which is perfectly a priori, and we find ourselves in possession of it without knowing how it came.

10. The author calls judgments of identity analytic, without identity synthetic, example

bodies are extended. Analytic

bodies are heavy. Synthetic

So that all judgments grounded on appearance are consequently synthetic.

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13. There are also synthetic judgments a priori (as well as all analytic) but with them experience is out of question. Ex. Whatever happens must have a cause. What is this x or unknown principle upon which this assertion is grounded? When it affirms B as praedicat [*sic*] of A. It cannot be experience. Bodies are heavy, for instance; is grounded on experience, and the greatest value of the assertion can go no further than to say all bodies that ever I have seen or tried are heavy. But when we affirm that whatever happens must have a cause we judge without reserve and absolutely, and consequently experience is out of question.

14. Mathematical judgments are all synthetic. They must all be a priori because they include necessity, which cannot be obtained by induction from experience.

15. An elegant example is given thus 7+5=12

This requires a mental inspection (Anschauung)

The ideas of 7 and 5 are only the ideas of 7 and of 5. The idea of 12 is a different one perceived by ment. insp.

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16. All mathematical axioms are synthetic. Ex. a straight line between 2 points is the shortest. There also mental inspection is required.

17. Natural philosophy contains also synthetic judgments a priori. Ex in all the changes that happen to matter the quantity of it remains the same. Ex. Action and reaction are equal.

19. Question. How are synthetic judgments a priori possible. This was a stumbling block to David Hume. And by thinking that these judgements a priori were quite impossible he annihilated all sciences, and reduced them to custom, and probable induction from experience.

20. The question as stated in general includes all sciences. How is mathematical knowledge possible? How is knowledge in natural philosophy possible?
20. These questions are very proper for since for instance we have mathematical knowledge it cannot be amiss to examine

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how we came by it.
But is metaphysical knowledge possible is a question that will not be so proper to examine till we know that there is such a thing.
22. We ought first of all to enter into a critical examination of the understanding.
23. This cannot be so very extensive because we are not to examine the endless objects of the understanding, but the faculty itself and the actions of it that spring up as if it were in its bosom. Then having ascertain [*sic*] what the understanding has from experience we may there also examine what its extent may be beyond experience.

24 Critical investigation of the pure reasoning faculty
26 It may be called transcendental critic [*sic*]
29. That there are two branches from perhaps only one (but to us unknown root) a power of sensation (Sinnlichkeit) and Understanding (Verstand)

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33. Mental inspection. Intuition. Anschauung.
This requires objects. The mind must be acted upon, affected. The capacity we have of being thus acted upon is that of sensation (or receptivity). Only this can give us what is necessary for mental inspection. But the understanding thinks upon them and hence springs up conceptions or ideas
33. All thinking must in the end relate to an inspection of objects furnished by sensation
34. The effect of objects upon the imagination (Vorstellungsfähigkeit) is sensation. The mental inspection of the sensation is experience. The unknown object which causes it, is, in the mind, an appearance.
This may be called the matter. The form of it is what remains in the mind. This may be produced a priori in the mind independent of all actual sensation.

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37. Of space

Our idea of it is not empiric [*sic*], for it must be the foundation of our seeing objects in different place [*sic*] and precedes it.

It is a necessary idea a priori without which no mental inspection of impressions can be conceived to that place. It is condition belonging to the possibility of appearances.

It is not a conception of the order of the objects observation [*sic*]: there are many orders of things but there is only one space. If you break of [*sic*] many spaces you only mean different parts of the same space.

It is essentially one and it is perceived a priori by mental inspection.

Geometrical axioms for ex[ample] that the two sides of a triangle are bigger than the third are equally mental inspections a priori relating to space.

48. Time is perceived by mental or rather internal inspection a priori

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48 The idea of time gives the possibility of change for ex. A body cannot at the same time be in motion and at rest. The rest of the work till 58 is obscure and confused. It appears to be contradictory

59. All our ideas are only representations of appearances; the things themselves we perceive by mental inspection are not that for while [*sic*] we take them; and, as <u>appearances</u>, have no other existence but in the mind, even space and time included. What these things really are remains totally unknown.