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Kant's Natural-Scientific Output

Essay review of Immanuel Kant. *Natural Science*. Edited by Eric Watkins, translated by Lewis White Beck, Jeffrey Edwards, Olaf Reinhardt, Martin Schönfeld, and Eric Watkins. Cambridge University Press, 2012; xviii+802 pp. ISBN 978-0-521-36394-5 (hardback). Price not shown.

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Our scholarly predecessors used to speak of Kant as a *Naturforscher*, an investigator of nature. That activity, we must remember, was wider than a preoccupation with the sort of issues that attract philosophers of science nowadays. To be sure, a *Naturforscher* would care deeply about the epistemology of mechanics and the metaphysics of gravitation theory. But he would be just as interested in the meaning and range of conservation laws, the genesis of stellar systems, the exact mechanism of earthquakes, volcanic activity on the Moon, wind patterns, and the evolution of islands. Kant was such a figure.

Inevitably though regrettably, our current division of labor has affected the publication in English—and so our perception—of Kant as an investigator of nature. We have from Michael Friedman an outstanding translation of *Metaphysical Foundations of Natural Science*. In the early Nineties, Eckart Förster and Michael Rosen gave us a good sample of Kant's foundations of field theory (anachronistically speaking), as part of his doctrine of ether in the so-called *Opus Postumum*. Those volumes, though important, might give us a skewed image of Kant as drawn exclusively to philosophical foundations for exact science. Now, under Eric Watkins' masterful editorship, we get a wider, more balanced view of Kant's interests and disquisitions about physical nature. For lack of a better term, these pieces have been collectively entitled 'natural science.' That should not blind the reader to the fact that, next to insightful, important results in empirical science, Kant also offers important contributions to the conceptual foundations of classical physics. It is, as the editor notes, "natural science broadly construed" (p. x).

The volume opens with Kant's first essay in natural philosophy, his *True Estimation of Living Forces*, from 1747. There, Kant wrestles with a problem that divided much of Continental Europe in the early Enlightenment: what is the proper measure of the "force" that a body in motion has? For Leibnizians, it was *vis viva*, or 'live force' defined as mv^2, or twice the kinetic energy. For disciples of Descartes and Malebranche, it was *la force du mouvement*, a 'moving force' equal to mass times speed or velocity. (Though some Newtonians, like James Jurin, intervened in this debate, the question really has no place in Newtonian mechanics, which is a theory of impressed forces, not 'forces of motion.') Kant seeks to mediate between the two warring parties, Leibnizian and Cartesian. His conciliatory solution is to distinguish between two notions of body and force, mathematical and metaphysical. For mathematical mechanics, Cartesian $m\mathbf{v}$ is the right measure of force; he too would adopt it, starting in the late 1750s. Metaphysical force is the "inner striving" of a body that "bases its motion sufficiently on itself" (p. 124), which is Kant's way of denoting free translation in a vacuum. The measure of the latter is Leibnizian mv^2.

Conventional wisdom still has it that in 1743 d'Alembert "solved" the *vis viva* controversy, by showing that both Leibnizian 'live force' and Descartes-Malebranche *force du mouvement* have a rightful place in mechanics. From this perspective, Kant's attempts in 1747 to estimate a single measure of 'force' appear misguided and out of date. And yet, it is the conventional wisdom that errs, both historically and philosophically. D'Alembert's "solution" relies on an assumption and a decision. The assumption is that mechanics must be grounded in definitions, subject to the constraints of his theory of definitions (see Le Ru 1994). But this bypasses entirely the issue of which measure of 'force' has more evidential support—and it is not clear that *both* measures are equally confirmed by experience. The decision is to ignore a premise that *everyone* then shared, viz. that mechanics properly grounded rests on a *single* dynamical principle not several. To see the pull of this idea in the Enlightenment, consider: Lagrange in 1788 derived all of particle dynamics from one law, the Principle of Virtual Work; and Euler in 1776 rested all mechanics on one principle, the Second Law generalized to impressed forces and torques. But, if mechanics rests on a single law not two, only one measure of force can be fundamental, despite what d'Alembert believed. So, in a sense, Kant was right to keep looking for it. Unfortunately, Kant's monograph fell flat in Germany. A review in the *Nova Acta Eruditorum* noted it unenthusiastically and moved on, put off by Kant's taxing style (see Anonymous 1751). This youthful work, however, did provide Kant with insights and an agenda for his later 'dynamics,' or theory of matter, and his mechanics of action by contact.

Next comes the justly famous *Universal Natural History, or Theory of Heavens*. The work is in several parts, however its central project, and key to its long-standing reputation, is a proof of possibility presented as a cosmological speculation. Starting with nothing but 'Newtonian' elements—a nebula of mass distributed in uniformly decreasing density around some heavier "elements," the Second Law, and two universal forces, viz. gravitation and repulsion—Kant aims to show that he can explain the birth of relatively stable cosmic structure: rotating galaxies nested inside larger, spinning clusters; and, inside the former, stellar systems such as ours, with planets orbiting around a central body.

The publication in English of a scholarly edition of Kant's *Theory of Heavens* is especially timely. Developments in 20-century cosmogony have led to renewed interest in Kant's insights. After a long period of neglect, planetary system formation from an initial nebula of matter received a new lease on life with Safronov 1972 and Prentice 1978. To be sure, these modern accounts are vastly more sophisticated than Kant's largely qualitative speculations. And, they include extra-mechanical initial conditions and processes, e.g., temperature or entropy gradients, magnetic braking, ionization, radiation transfer, etc. Still, it is instructive to see that the same problems that beset Kant also plague modern accounts; and if they seem to do better, it is really because they sweep Kant's problems under the rug. A telling example is the origin and evolution of angular momentum. Kant's account suffered from two difficulties, both having to do with rotation.

The first is that Kant starts with "universal rest" as an initial condition (p. 228). In modern terms, his global system is non-rotating. Then it is a mystery how any matter could end up in *orbiting* clumps, the planetesimals out of which larger planets will then form. Kant offers a sleight of hand: infalling particles, attracted by the heavier ones dispersed throughout, collide as they fall and somehow acquire a sideways motion enough to keep them in stable orbits. "[T]he elements descending to their attraction points are deflected from the straight line of their motion to one side, and the vertical descent ultimately changes into orbital motions encompassing the center point of the descent" (p. 229). This appears physically impossible: angular momentum is conserved, so there can be no net rotation—that is, collective orbiting around some axes—from zero initial rotation. (Laplace, for instance, was aware of this difficulty, and so he started with a slow-rotating nebula.) If the initial condition is a molecular cloud at rest, the result will be gravitational collapse and the birth of a star, not a star and a planetary system (see Larson 1968, 1-25). To get around this difficulty, modern accounts start with a nebula that already has some angular momentum. But this initial condition is either *assumed* without explanation or is explained from *hypothetical* causes: a passing star impressing a torque on the cloud; or a pre-formed star capturing its nebula as it passes through a rotating galaxy or molecular gas cloud. So, these accounts ask to be granted what Kant could not prove.

The second problem stems, again, from angular momentum. Its conservation entails that, as the (already-spinning) nebula contracts, with matter falling into the now rotating core, the nascent proto-Sun will spin ever faster—a good deal faster than the actual Sun, containing as it does over 99% of mass in the Solar System. However, in our Solar System, about 99% of angular momentum comes from the *planets*, not the central star, as a nebular hypothesis would predict. This discrepancy between the observed and the predicted rotation of the Sun led many, in the 19th century, to regard as dead ends the nebular accounts of Kant, Laplace, and Herschel (see Woolfson 1993). Here too, Kant's problem plagues modern accounts as well. As it approaches the center, conservation of angular momentum may result in too much infalling matter acquiring enough lateral velocity to settle into stable orbits before the core acquires enough mass to turn into a star. And, orbiting matter may spin too fast to allow planetesimals to coalesce into planets. To deal with this problem, modern accounts (1) invoke various mechanisms for shedding angular momentum or recirculate it away from the core (e.g., Walker 1994, Balbus 2003). Or (2) they start with a pre-existing, slowly rotating Sun capturing later a nebula whose condensation then results in planets being born (Woolfson 1993). But (1) is not fully understood, and (2) differs crucially from Kant and Laplace.

Among the many jewels in this volume is also a little known piece from 1758, entitled *New Doctrine of Motion and Rest*. The piece is significant in many ways. It shows the young Kant already engaged in the debate over absolute and relative motion, a philosophical back and forth that started with Descartes and Newton, and continues to attract thinkers nowadays (see Hoefer 1998). Remarkably, it shows Kant defending relationism, the doctrine that all motion is 'relative.' This is the very opposite of what we would expect from Kant, who had allegedly signed up to Newtonianism wholesale three years before, in *Theory of Heavens*. (Now we know that the truth is more complicated; Watkins 2013 spells out cogently the several ways in which Kant's cosmological book endorsed, and distanced itself from, Newtonianism.) More importantly, the piece is the core of some key ideas in Kant's later philosophy of physics, viz. his concept of necessary motion and synthetic a priori laws for impact dynamics, in the *Metaphysical Foundations of Natural Science*.

There are, in addition, brief but insightful pieces on the genesis and dynamics of trade winds, the long-term effects of tidal friction on the Earth's rotation, the probable cause of earthquakes; and the question—which drew many first-rate Enlightenment minds, including Euler and Madame du Châtelet—of the nature of fire. Two things are notable about Kant's treatment of the latter. One is that, to explain the nature of fire, he introduces in 1755 a pervasive, imponderable ether, which will eventually take center stage in his late, post-Critical natural philosophy. Another is Kant's unifying drive, already on display here. His ether is by definition attractive, elastic and ductile—and so Kant postulates it as a single explanatory ground for general phenomena such as cohesion, elasticity, and heat and light transmission.

Almost half of the volume is taken up by Kant's lectures on physical geography, richly and helpfully annotated. Kant lectured on that topic for nearly four decades, with much success. This work abundantly shows him as a man of the Enlightenment, an age as keen to map, chart, catalog and index the Earth as it was to push the boundaries of mathematical physics. It is an eye-opening lesson to see Kant follow, well into maturity, the latest results in Earth science or physical anthropology. The man who taught us so much about the synthetic a priori also spent countless hours acquainting himself with the a posteriori at home and abroad. However, some of this acquaintance was mediated by often unreliable and tendentious reports by explorers and missionaries. Kant on Florida: “the people are very courageous, they sacrifice their first-born to the sun” (p. 677).

In a statement of policy appended to each volume, the general editors behind the Cambridge Edition of Kant's works confess their preference for literal over readable translation, in order to “leave as much of the interpretive work as possible to the reader” (p. viii). That desideratum, commendable for works in ‘core areas’ of philosophy, can lead to opacity in historical texts in natural philosophy. An example is having Kant talk about the “force of a spring-hard body in its impact” (p. 49). To the modern reader, ‘spring-hard’ is mysterious, unless she knows that Kant coined it to denote a peculiar entity, a rigid body that is flexible (so that it may rebound). That seems a *contradictio in terminis*, but early 18th-century figures found a way to avoid it; they introduced ‘infinitesimally soft’ bodies that would allow them to have it both ways: incapable of finite deformations, these bodies counted as ‘hard,’ or rigid. But, their infinitesimal flexion made them able to rebound in impact, just like a flexed spring. It is the type of body handled theoretically by Johann Bernoulli in *Discours sur les loix de la communication du movement* (1724-6), an influential paper on the laws of collision.

Before I conclude, some very slight emendations. Note 14 on p. 707 refers to James Bradley as having discovered an aberrant motion; that combines two separate discoveries by Bradley—the aberration of light, and the Earth’s nutation. Note 96 on p. 707 mis-references a key paper by Daniel Bernoulli; it appeared in volume I (1728) of *Commentarii Academiae Scientiarum Petropolitanae*, which note 97 correctly identifies. Maupertuis’ *Discours sur la figure des astres* was originally published in 1732 not 1742, as note 16 on p. 708 has it.

In sum, this volume is a much needed, very valuable contribution to scholarship. It brings together important texts by an important philosopher, readably translated and edited to the highest standards in the field. It will easily become the new reference work on Kant’s natural-scientific output, and will foreseeably remain the standard text for decades to come. The translators did a superb job, patiently toiling at sometimes-thankless work to give us admirably clear renditions of Kant’s notoriously convoluted writing. It is not lost on this reviewer how difficult it is to translate and annotate these texts, and he hopes the reader will see that too and appreciate the translators' achievement. A special commendation must go to Eric Watkins, whose choice as editor was particularly felicitous. When Watkins took over the editorial helm, the ship had been adrift for some years. His unique combination of philosophical acumen, deep familiarity with Kant, and peerless knowledge of 18th-century science enabled him to see the project to a splendid completion. In many ways, the scholarly quality of this volume surpasses its counterpart in the *Akademie-Ausgabe* of the works of Kant. Watkins is now the worthiest successor of his eponymous curator of Kant's science, Erich Adickes.

References :

Anonymous. 1751. "Review of Immanuel Kant, *Gedancken von der wahren Schätzung der lebendigen Kräfte*," *Nova Acta Eruditorum* 3, 177-82.

Balbus, S.A. 2003. "Enhanced Angular Momentum Transport in Accretion Disks," *Annual Review of Astronomy and Astrophysics* 41, 555-97.

Hoefer, C. 1998. "Absolute vs Relational Spacetime; For Better or Worse, the Debate Goes On," *British Journal for the Philosophy of Science* 49, 451-467.

Larson, R.B. 1968. *Dynamics of a Collapsing Protostar*, Ph.D. Diss. California Institute of Technology.

Le Ru, V. 1994. *D'Alembert philosophe*. Paris: Vrin.

Prentice, A.J.R. 1978, "Origin of the solar system," *Earth, Moon, and Planets* 19(3), 341-98.

Safronov, V. S. 1972, *Evolution of the Protoplanetary Cloud and Formation of the Earth and the Planets*, Jerusalem: Israel Program for Scientific Translations/Keter Publishing House.

Walker, C.K. 1994. "The Early Stages of Protostellar Evolution," *Bulletin of the American Astronomical Society* 26, 1840.

Watkins, E. 2013. "The early Kant's (anti)-Newtonianism," *Studies in History and Philosophy of Science* 44.

Woolfson, M.M. 1993. "The Solar System—its Origin and Evolution," *Quarterly Journal of the Royal Astronomical Society* 34, 1-20.