Laborious Nature:
Simon Schaffer and the History of Science

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How do scientific discoveries and progress come about? Against an idealist and triumphalist conception of the history of science, Simon Schaffer's *oeuvre* examines science in the making, in close proximity to its practices and actors. Far from diminishing its prestige, this approach restores science to the central place it occupied in Old Regime societies.

The "Scientific Revolution" of the eighteenth and nineteenth centuries is traditionally described as a key moment in the foundation of a modern science based on universal principles, justifying a new architecture of knowledge, recasting epistemology, and restoring critique and reason to their full powers. It was long thought that Science (with a capital "S") had emerged in the seventeenth and eighteenth centuries with the advent of a form of rational thought founded on abstraction and detachment from temporal and spiritual authorities. Born in the West, scientific thought, with its immediately universal scope, was said to have conquered the world—while helping Europe do the same. If this traditional and often triumphalist conception of the "Scientific Revolution" is no longer in favor, it is largely due to the work of the great British historian Simon Schaffer and his colleagues. An overarching concern found throughout his work is that of rendering intelligible the connection between the exact sciences, culture, and power between the seventeenth and the late nineteenth centuries, while recovering all the fumbling, hesitation, and dead-ends which marked the birth of experimental culture as an historically and socially situated phenomenon. The language of the exact sciences is inseparable from the cultural, spiritual, social, economic, and political transformation of old regime Europe. His latest book, *La fabrique des sciences modernes* (The Making of Modern Science), consisting of articles that have appeared in English since the 1980s, provides an occasion to reflect upon a unique trajectory through the history of science [1].

Schaffer, Cambridge, and the History of Science

For the past thirty years, Simon Schaffer has taken the history of science in new directions. Trained in physics, philosophy, and the history of science at Cambridge University in the 1970s, he first worked at Imperial College in London at the Center for the History of Science and Technology, before joining the department of the history and philosophy of Cambridge, where he has taught ever since. His intellectual project is inseparable from the pedagogical endeavor that has made Cambridge a center for the history of science, not only in the United Kingdom but throughout the world. This reputation is due to its unique intellectual profile, which results from blending the classic perspectives of the history and philosophy of science (HPS), which have

been found in universities since the 1920s, with the social sciences, particularly the sociology and anthropology of science. Thus Cambridge was able, far better than many heritage institutions, to absorb the critique of the sciences that emerged in Great Britain and across Europe in the 1970s and 80s. Without renouncing its discipline's foundations, the HPS department gradually opened itself to the methods of the emerging field of "science studies," while also approving of innovations on the continent. Schaffer was thus instrumental (with Jim Secord) in promoting the circulation of these ideas, and helped to accustom historians of science to the views of the Edinburgh and Bath sociologists of science and the Center for the Sociology of Innovation at the École des Mines in Paris (notably Michel Callon and Bruno Latour), while working in collaboration with the journals *Social Studies of Sciences*, *History of Science*, *Sciences in Context* and *The British Journal for the History of Science* to recontextualize modern science. Taking advantage of Cambridge's central place in the British and the global university system, he trained an entire generation of historians of science and, with their assistance, formulated a new theoretical agenda for the study of modern science. This is apparent in the series of books he co-wrote with his fellow scholars beginning in the early 1990s, which addressed with the Royal Society scholar Robert Hooke and the uses of experimentation; the astronomer William Whevel; science during the Enlightenment (1999); artisans; and middlemen (2010).

An Archeology of Experimental Culture: Science as Practice

Schaffer's starting point is practice, not concepts. Practice is the basis of science's distinctive character as a form of knowledge, but also, more broadly, as an early modern culture. Rejecting the traditional agenda of the history of science, which attempts to identify the emergence of modern science's key concepts (proof, validity claims, and so on), he undertook, by focusing on experimental culture, an anthropology of modern science, specifically demonstrating the ways in which science and politics overlapped beginning in the seventeenth century. Deeply influenced by the renewal of interest in science among social scientists in the 1970s and 80s, particularly the sociology of scientific knowledge, he was receptive to the analytical tools proposed by Michel Foucault for deciphering institutions of knowledge and scientific disciplines.

To understand the task of scientific "problematization"—be it the study of tides, the identification of Halley's Comet, earthquakes, the personal equation in astronomy, or the work of Galileo, Newton, Delisle, Dufay, Lavoisier, and Herschel—is to grasp scientific innovation as a dynamic social process. Historians are thus liberated from the binary opposition between science and context when they examine the "seamless" relationship between society and scientific production. This approach is also an invitation to unite social, political, religious, economic, and moral dimensions that have always been analyzed separately, due to a division of labor between the history of science and history as such. In this way, Schaffer offers a carefully examination of the various "mediations" through which experimental culture pulled science out of the limited sphere of the university, making it a public and political question in an age when absolutism was asserting itself. Thus a linear vision of science founded on the idea of progress gives way to an examination of the process whereby natural philosophy emerged as a network of experimental practices. This is true of the work in which he "attempts to grasp the process […] through which the air pump, the condensation machine, and the electrical machine came to occupy an important place" in old regime society [2]. Rather than simply accepting the dichotomy between externalist

and internalist approaches—since scientific concepts are constantly externalized and shared by the broader society, even as social practices (such as testimony, credit, and trust) are integrated into scientific procedure—what is required is a thick description of science. In an article from 1980, Schaffer uses Foucault's *The Order of Things* to show how the astronomer Herschel participated, from the standpoint of natural history, in creating a new episteme [3]. Rather than limiting himself to an institutional approach focusing on learned academies and scientific disciplines, he demonstrates the scale of a wide-ranging project that brought together scientific instruments, new spaces of knowledge, and new efforts to organize knowledge. This idea has led him, on several occasions, to call attention to "natural history's invisibility in the history of astronomy." [4]. The role attributed to temporality would become a key feature of Herschel's new astronomy.

The social history of sciences is characterized by its concern with "how science is made," "science in action," and "science as a practice or culture" in order to address a number of historiographical theses. Each study undertakes to trace, always chronologically, the discussion of a scientific problem and its practical resolution, often using a framework for analyzing controversies that was developed methodologically in the 1970s and 80s. No episode divides up or differentiates these spheres; on the contrary, they show how ideas and practices are translated and circulated from one realm to another. For instance, public lectures on electricity in the 1780s represented a way of mobilizing the public and political authorities to think about action at a distance and the nature of invisible and divine powers, while also valorizing the natural philosopher as a new prophet endowed with the mission of controlling these powers. The justificatory discourses and the controversies to which these experiments and observations gave rise shed light on the way in which religion, politics, and science were woven together in the process of conferring moral authority onto the man of science. This methodology, moreover, challenges the contrast between science and society (according to which the condition of possibility of universal truths lies in their capacity to extricate themselves from social determinations and contexts, the laboratory being the site *par excellence* of this constructed abstraction), emphasizing, instead, a testimonial epistemology that had hitherto been confined to secondary role. The testimonial epistemology brings to light a shift in the question of the authority and certification of knowledge, by emphasizing the social make-up of the audience witnessing these experiments. Thus, for Schaffer, scientific proof ceases to belong exclusively to the vocabulary of scientific work and appears as an eminently social practice. The collapse of the edifice of scholastic thought unsettled long-established definitions of certainty inherited from antiquity, the Middle Ages, and textual authorities. The guarantee of a stable and certain status that experimental practice required could no longer be provided by institutions of knowledge tied to the church. Absolutist culture demanded the integration of new social and political requirements, as well as a new grammar of practices. The attention given to words admitting multiple meanings, such as "trust," "virtue," and "credit," each of which belongs to several realms (i.e., morality, economics, and politics) is indicative of this effort to study objects located at the borders of scientific practice. It is the remarkable mobility and polyvalence of these concepts that allowed the sciences to achieve positions of legitimacy in academies as well as government ministries.

These major analytical reversals are evident as early as the first book he wrote with the historian and sociologist Steven Shapin, *Leviathan and the Air Pump* (1985) (5). In the controversy over

the void that pitted Hobbes against Boyle, the latter's strategy was to remove science from the usual circles of scholastic disputation in order to attract public support. To do so, he used an approach which involved relying, while conducting the experiment, on credible witnesses, often aristocrats, who could attest that the phenomenon had been accurately observed and that the experiment properly handled. Credibility and trust became the new foundations of experimental culture. It was within this "limited public space" that the techniques for producing and validating experiments were developed. The main question that preoccupied British social history of science was that of the scientific authority in a context of emerging experimental culture. The latter is distinguished by experimental practices that are attached to the idea of secrecy, which pervaded artisanal and alchemic circles, as well as by a conception of intellectual authority that was tied to scholasticism. How could experimentation's results, which always depend on a particular set of conditions and are the result of negotiations between various parties, acquire the status of universal scientific truth? Studies on the experience of experimentation and the concrete conditions in which it occurred displace two traditional interpretations. First, the analysis of experimental mechanisms brings to light a new scientific geography. The spectacular element of science's visibility does not arise solely from scholarly concerns, but from multiple cultural spheres and sites. The spectacle of artificial illusion and the display of machines in public places, as well as some scholars' curiosity cabinets, invite us to reformulate the problem of scientific popularization and science's social diffusion. In the eighteenth century, Newtonian ideas spread through public demonstrations and inventions occurring in city taverns that brought together philosophers, practitioners, and entrepreneurs.

Furthermore, this approach helps us to see the sociology of early modern science in a new light. The mobilization of the public in this endeavor changed the importance given to publicity and spontaneous agreement in establishing scientific facts. Because of the new ways in which the public was involved, experimentation allows the historian to measure the effectiveness of knowledge elaborated in this "social interplay between action and scientific utterances." The appeal to the public and the creation of visually based forms of certification partially account for the popularity, in the history of science, of the concept of sociability, understood as a face-to-face ritual. For Boyle, the scientific community, the model of an ideal society, had to be founded on the mastery of affects, resulting, from a literary perspective, in strict editorial and rhetorical controls. The implementation of discursive protocols in learned academies was a way of excluding from the field of science ordinary verbal violence and promoting the peaceful regulation of disagreement.

The social character of natural knowledge, a theme that was already present in this book from 1985, is identified as a mass phenomenon, constituting a point at which the controversy surrounding experimental knowledge intersects with the very definition of political order. At a time when England was just emerging from its Civil War, the question of the protocols for and the constitution of a scientific consensus validated through experiments and civility echoes debates over political authority and civil peace. Schaffer thus sets out to describe the various ways in which public experiments could be defined. By distinguishing, for example, between the more practical genre of the "assay" preferred by Galileo and the more philosophical and literary essay favored by Bacon, he shows how, in the early modern period, experimental culture was the object of several competing discourses and practices. [6]. That said, Schaffer, complicates and

pluralizes a history that is often told in a linear mode as story of the epistemological conquest of one of contemporary science's key practices.

Disciplining Practices: The Material Turn in the History of Science

The archeological method, however, makes another demand. By encouraging us, in the wake of science studies, to see experimental culture as something other than a collection of norms and protocols, the historian of science must seek the instruments, systems of constraints, and disciplines that it harbors. The attention given to place, and in particular to scholarly institutions, instruments, timetables, and work allows us to address the question of power from below.

The emphasis on the micro-powers that organized experimental practice and the assertion of absolutist culture is a way of determining the extent to which the exact sciences can be considered disciplinary technologies (this can be seen, for instance, in the way the social world of the Cavendish laboratory was divided between professors, students, and servants). In exploring the various worlds in which exactness and precision were developed and produced as so many guarantees of modern science's truth program, Schaffer places textual, economic, social, and material assemblages at the heart of his analysis. The latter governed scientific representations and maintained faith in modern science from the eighteenth to the nineteenth centuries. If the social sciences, and the history of science in particular, have recently focused on wide-ranging "regimes" (Dominique Pestre), Schaffer has, for his part, sought to emphasize "*dispositifs*," which are more localized, mobile, and small-scale. These "*dispositifs*" are often identified by observing a technologies and instruments (such as the eudiometer or the refracting telescope) that offer themselves as "material and normative arrangements" for formalizing, categorizing, and defining nature.

In this way, the Cambridge history of sciences is mindful of the materiality of science, its objects, and its instruments. The renewed interests among sociologists, anthropologists, and historians for material culture has played a part in this development. An entire sub-field is devoted to expanding our knowledge of the material culture of scientific work in the early modern period. In the first place, this means recognizing the importance of objects and their "lives" in the making of science: in other words, the instruments, equipment, and machinery that are part of the process of constructing scientific facts. Schaffer's work has undoubtedly gone the furthest in rehabilitating instruments and machines as objects of study, notably in the way he emphasizes the importance of material networks in establishing the universality of scientific results (a point to which we will return) and calls attention to the gradual and problematic process whereby scientific objects have become increasingly autonomous. The laboratory and the observatory appear as enclosed and disciplined spaces, similar in this respect to the asylum, the hospital, and the barracks. They are the spaces *par excellence* in which scientific practices are internalized.

These systems of constraint are not, however, limited to the spaces in which science is produced. Here, too, Schaffer, drawing on the concept of performance, shatters the notion of a closed scientific world based on a separation of spheres, a division of a labor, and a strictly hierarchical relationship between production, diffusion, and reception (and perhaps even popularization). In the way they used scientific spectacles to explain electricity, earthquakes, and air measurements,

Enlightenment *philosophes* conceived of scientific practice as an eminently public task, grounded in a genuinely spectacular epistemology. Eighteenth-century science was not made solely in the isolation of the laboratory, but was a collective endeavor that was negotiated in public spaces and performed before an audience. Thanks to Schaffer, scientific practice is now seen as an ongoing and transformative process, which does not pit scientific professionals, on the one hand, against amateurs and artisans, on the other. Artisans, like dyers and jewelers, helped to improve the experimenter's technique. Conceived in this way, the scientific community finds its boundaries considerably broadened through the integration of practical knowledge.

This leads to a simple question: why did Western science need this world of scientific objects in order to pursue its intellectual project? Why did the "Scientific Revolution" come to rely on the instrumentalization and the multiplication of artifacts? In addition to providing a history of experimental culture, Schaffer show how porous and problematic the boundaries between nature and artifice, as well as the human and the non-human, could be from the seventeenth to the twentieth century. The attention given to the multiplication of automats through Europe during the Enlightenment, for example, attests to the political and social impact of this conquest of instruments and philosophical objects. These machines made it possible to philosophize in new ways and conceive of a new society, which engineers projected onto an artificial universe [7]. But this society of automatons was not neutral. It did not simply participate in a rhetoric of technological progress; it gave birth, through its celebration of "constructed humanity," to the notion of a "parliament of monsters" that would speak in humanity's place and stead. The introduction of eudiometric machines to measure air quality occurs at the juncture of medicine, hygienics, and a revolution in chemistry. By exploring the construction of these instruments and their uses, Schaffer offers us a portrait of the practitioners and reformers who, from England to Tuscany and Milan to Versailles, tied the study of gas to political and environmental concerns. In this ways, he inscribes science into a political economy in which the proliferation of instruments is symptomatic of the rise of government by experts

Universalization through Practice

The archaeology of the exact sciences (primarily astronomy and the experimental sciences) requires in the first place the localization of practices and a "territorialization" of science. Beginning in his first books, Shaffer stepped away from epistemological discussions over modern science's inherent universality. Postmodernism's and cultural relativism's challenge to science's universal basis has reignited the debate. As Ilana Löwy writes, the discussion is premised on a hidden assumption: "If nature is universal, stable, and obeys immutable laws, it follows that (good) science is universal, too. Yet this assertion is far from being evident. First, because science's universality has a history, its transnational character is relatively recent in humanity's history. Next, this universality would seem to depend closely on the conditions in which it was elaborated and circulation

What Pierre Bourdieu, following Eugène Garfield, viewed as a twofold process—simultaneously social and logical—based on normative conventions established between scientists and a capacity to reason on the basis of universal criteria (which Bourdieu describes as "socio-transcendental"), Schaffer sees as a problem of the social and spatial distribution of scientific resources [8]. According to Bourdieu, "[t]he epistemologists ignore this transition and the

transmutation to which it gives rise, but sociologists who identify making-public with publicity are no better placed to grasp its *inseparably epistemological and social logic,* the very logic which defines the socio-logical of verification." [9] Though *Leviathan and the Air Pump* had already addressed the question of the universalization of experimental culture, Shapin and Shaffer had initially focused their attention on the analysis the specific mechanisms whereby experimental results were brought out of laboratories and generalized. Knowledge does not circulate because it is universal; rather, "it is because it circulates that it can be universal." If the irreversible character of scientific results obeys a procedure of detachment, it is less because human ability to understand is universally shared than due to the routinization of scientific practices tied to the standardization of the use of tools and techniques. Terry Shinn and Pascal Ragouet observe: "it is in the course of these processes of decontexualization and recontextualization in different sites that a form of what one might call practical universality emerges." [10]. The instrumental universe brings together different sites by circulating the same techniques of manipulation, the same forms of action, and the same vocabulary to characterize their work. It is the instrument's generic character that allows a common scientific language to be created: "the universal character of instrumental knowledge lays in the relevance that is attributed to it independently by various fields" [11]. As one can see, far from being a spontaneous process, this universalization was costly work, requiring significant investment, the outcome of which could never be taken for granted. The "forgetting" of the social conditions of production would thus seem less to be a denial of particularity, than an effect of the routinization that was introduced with experimental practices and the circulation of measurements and standards. In this analytical framework, universalization was driven by the repetition at the local level of these same experiments, which also made them fragile. It is thanks to negotiated standardization and the production of a common language and practices that the exact sciences were triumphant in the nineteenth century, as Schaffer demonstrates in his study of the "making" of the ohms standard in electromagnetic research (which made possible, for instance, the invention of the telegraph) [12].

A World of Middlemen

To the conception of modern science premised on the transparency of the universal and the diffusionist view—what one might call the Westernization of modern science—which seeks to explain how the scientific revolution spread across the globe, Schaffer prefers to study the forms and practices through which science was universalized by exploring local contexts at a global level. For over a decade, his work has indeed struck out in a new direction, relentless questioning the role that science has been given in the grand progressive and critical narrative imposed by global history. To these local and situated laboratory studies, he has added a more globalized approach, marked by field science.

In his article "Newton on the Beach," this shift becomes representative of a new approach in the history of science [13]. Returning to the enigma of Newtonism's influence, not after Newton, but in Newton's own time, Schaffer examines the connections between the capitalization of information in England at the turn of seventeenth century and the emergence of Newton's major work, the *Principia.* Behind the revolution of the *Principia*—a symbol of the Scientific Revolution if ever there was one—Shaffer identifies an information order with universal aspirations. Though Newton never saw the sea, Newtonian science was completely shaped by

corresponding astronomers across the globe, ranging from merchants or Jesuits. Yet this information network was not immediately accepted and its credibility had to be established [14]. Schaffer undertakes a "connected textual history" of Newton's work. He not only identifies, using a genetic approach, different layers of text (as he had in the 1980s [15]), but he also reveals the geographical basis of Newton's knowledge, in which data-gathering resembles the practices of natural history. It becomes apparent that local informants and middlemen were essential to the information order that Newton used and that it blurred the boundaries between science, commercial data, and espionage. Monopolizing and controlling information now count among the primary concerns of the state, merchants, and scientists, following similar modalities. This collusion turned science into one of the engines of imperial conquest. In this context, the knowledge of nature was instrumentalized not only to achieve mastery over nature; it was also essential to recognizing and identifying imperial projects as such. The relationship between science and empire was not ancillary. They were consubstantial: the authority of science asserted itself as form of soft power, which proved supple and efficient in managing European expansion that was often confined to a few isolated trading posts: "I wanted to know if biopolitics existed for exact sciences, field sciences, and voyages" [16].

In a recent collective volume, *The Brokered World* (2010) [17], Schaffer and his team go further, by examining the context of the late eighteenth century as it relates to Edmund Burke's famous remark from 1791: "The world is governed by go-betweens." Burke knew from his experience in politics (as a member of parliament and a leader of the Whig party) that the question of mediations lay at the heart of British political system. He was, for instance, caught up in the corruption trial of the East India Company and its governor general, Warren Hastings. According to his defender, Joseph Price, middlemen were indispensable. In his defense, he demonstrated that these middlemen held the British Empire together, despite the fact that metropolitan politicians saw them as little more than agents of corruption. Nicholas Dirk has shown how the British Empire was built on this scandal. According to Schaffer, this episode is emblematic of the controversy surrounding the use of middlemen between the late eighteenth and early nineteenth centuries. Should they be given political roles? This political practice implied a new economy of knowledge that took seriously and valued (perhaps excessively) local knowledge, middlemen, and localized information systems. The point of importing this conversation into the field of the history of science and knowledge is not only to interrogate the expansion of the debate over middlemen, mediators, and go-betweens—in which various fields of knowledge, such as anthropology and history, have participated—but also, in particular, to reflect on how it was politicized. The image of the colonial scientist often appears in the literature as highly depoliticized, or is, to the contrary, identified with that of a bureaucrat or an administrator and is, in this way, completely influenced by the paradigm of expertise.

By choosing a narrow context and a comparative approach, the book's project is to test the hypothesis of a "go-between" moment. Before the new empires of the late eighteenth and early nineteenth centuries were created, the established colonial order was called into question (between colonialism's first and second stage), which upset the existing knowledge regime by challenging its contribution to different information orders. The choice of this narrow timeframe corresponds, in the scientific realm, to the shift from the first to the second "Scientific Revolution" of the nineteenth century: the emergence of new disciplines and technologies and new state forms, and the abandonment of natural philosophy. It allows one to emphasize the

destabilization of traditional reference points and the reconfiguration of practices that took place over several generations. On the cusp of natural philosophy and science, older empires and modern colonialism, the global examination of the question of middlemen allows one to dispense with the notion of a global Scientific Revolution conceived as a European export, modeled on the Industrial Revolution, and to shed light on the network of places, connections, and transition points between various scientific cultures and various conceptions of nature based on contact situations (Calcutta, Brazil, Japan, etc.). By tracing this pattern, Schaffer makes visible the numerous mediators—human or non-human, ideal or material—which helped hold together this new, unified representation of nature as something to be mastered and conquered. Rather than a full world, he wants us to see a world of archipelagos. Meanwhile, Schaffer, still using Newton as his marker, has continued his study of the translations and adaptations of modern science from Persia to Bombay and from Calcutta to the Pacific Ocean. By examining the controversies accompanying the ways in which Eastern astronomers contributed to its intellectual and practical circulation, he shows the difficulties and impasses arising from encounters between local astronomical cultures and Britain's scientific empire and this empire's fragility. Scientific practices, because they are caught up in the project of disciplining nature and man, are particularly useful in showing antagonisms and "understanding the murderous effects of the physics of power" [18].

As a result of examining scientific practices for thirty years, Simon Schaffer has made a decisive contribution not only to the history of scientific practices, but to history as such. By always attempting to connect specific cases, places, practices, and levels, he has relentlessly shown it is possible to do the history of science in a way that transcends the cleavage between externalist and internalist approaches, as well as the great ideological divide between modern science and non-Western science. By blurring these well-established lines, he has turned science into a new object for the twenty-first century historian and put the history of sciences on the agenda of broader historical research.

Notes

[1] We draw here in particular in the essays that were republished as Simon Shaffer, *La Fabrique des sciences modernes*, Paris, Le Seuil, 2014. See, too, *Trabajos de cristal. Ensayos de historia de la ciencia, 1650-1900*, Madrid, Marcial Pons, 2011.

[2] Schaffer, "Natural Philosophy and Public Spectacle in the Eighteenth Century," *History of Science*, 1983, n°23, p. 1-43.

[3] Schaffer, "Herschel in Bedlam: Natural History and Stellar Astronomy," *British Journal for the History of Science*, vol. 13, n°3, p. 211-239.

[4] Schaffer, "Taxinomie, discipline, colonies: Foucault et la Sociology of Knowledge," in Michel Foucault. *Un héritage critique*, Jean-François Bert and Jérome Lamy (eds.), Paris, CNRS Editions, 2014, p. 368.

[5] Steven Shapin, *Leviathan and the Air Pump: Hobbes, Boyle and the Experimental Life,* Princeton, Princeton University Press, 1985.

[6] Schaffer, "Golden means: Assay Instruments and the Geography of Precision in the Guinea Trade," in *Instruments, Travel and Science*, eds. Marie-Noëlle Bourguet, Christian Licoppe, and H. Otto Sibum, Basington, Routledge, 2002, p. 20-50.

[7] Schaffer, "Machine Philosophy: Demonstration Devices in Georgian Mechanics," *Osiris* 9, 1994, p. 157-82.

[8] Eugene Garfield, "The Obliteration phenomenon," *Current Contents*, 51/52 (5-7), quoted by Pierre Bourdieu, *Science of Science and Reflexivity,* Polity, 2004, p. 75

[9] *Ibid.*

[10] Terry Shinn and Pascal Ragouet, C*ontroverses sur la science. Pour une sociologie transversaliste de l'activité scientifique,* Paris, Raisons d'agir, 2005, p. 180.

[11] *Ibid.*, p. 181.

[12] Schaffer, "Victorian Metrology and its Instrumentation: A Manufactory of Ohms', in *Invisible Connexions: Instruments, Institutions and Science*, eds. Robert Bud and Susan E. Cozzens, SPIE Press, 1992, p. 23-56, reprinted in *The Science Studies Reader*, ed. Mario Biagioli, ed., Routledge, 1999, p. 457-478.

[13] Schaffer, "Newton on the Beach: The Information Order of *Principia Mathematica*," *History of Science*, 47, 2009, p. 243-276.

[14] *The Information Order of Isaac Newton's* Principia Mathematica, Uppsala University / Salvia Såmskrifter, 2008.

[15] Schaffer, "Newton at the Crossroads," *Radical Philosophy* 37, 1984, p. 23-28; Shaffer, "Newtonianism," in *Companion to the History of Modern Science*, eds. G.N. Cantor et al, Routledge, 1989.

[16] Shaffer, "Taxinomies, disciplines, colonies," *op.cit*., p. 371.

[17] Schaffer, Lissa Roberts, Kapil Raj and James Delbourgo, eds. *The Brokered World: Go-betweens and Global Intelligence 1770-1820*, Sagamore Beach, Science History Publications, 2009.

[18] Schaffer, "Taxinomies, disciplines, colonies," *op.cit*., p. 371.

Books&ideas.net, March 23, 2015.
First published on laviedesidees.fr, May 27, 2014. Translated from the French by Michael C. Behrent with the support of the Institut français.