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THE ANTHROPOLOGY OF INCOMMENSURABILITY

I. Incommensurability and Sterility

SINCE IT entered the discourse of history and philosophy of science with Feyerabend's "Explanation, Reduction, and Empiricism" and Kuhn's *The Structure of Scientific Revolutions*, the notion of incommensurability has problematized the debate on processes of theory-choice.[1]

According to Kuhn, two scientific paradigms competing for the explanation of roughly the same set of natural phenomena may not share a global linguistic common denominator. As a result, the possibility of scientific communication and dialogue cannot be taken for granted and the process of theory choice can no longer be reduced to the simple picture presented, for example, by the logical empiricists.

By analyzing the dialogue (or rather the lack of it) between Galileo and the Tuscan Aristotelians during the debate on buoyancy in 1611–1613, I want to argue that incommensurability between competing paradigms is not just an unfortunate problem of linguistic communication, but it plays an important role in the process of scientific change and paradigm-speciation.

The breakdown of communication during the dispute on buoyancy is not an isolated case in the scientific revolution. In canonical texts such as Descartes' *Le monde*, Galileo's various writings, Bacon's *Advancement of Learning* and *Novum organum*, and Locke's *Essay*, we find that the new philosophers claimed not to understand some of the fundamental concepts of the Aristotelians and refused to subject their own works to judgments based on the discourse of the older tradition.[2] For instance, in *Le monde*, Descartes quoted Aristotle in Latin, claiming to do so because — being unable to understand the sense of his definitions — he was unable to translate them into French.[3] Galileo's state-

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[1]P. K. Feyerabend, 'Explanation, Reduction, and Empiricism', *Minnesota Studies in the Philosophy of Science* 3 (1962), 28–97 (reprinted in P. K. Feyerabend, *Philosophical Papers* (Cambridge: Cambridge University Press, 1981), pp. 44–96); T. S. Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1962).

[2]F. Bacon, *Novum organum*, Book One, aphorisms XXXIII, XXXV, LX, LXIII; J. Locke, *An Essay Concerning Human Understanding*, A. Fraser (ed.) (New York: Dover, 1959), Vol. II, pp. 34–35.

[3]René Descartes, *Le Monde, ou Traité de la lumière*, M. S. Mahoney (ed.) (New York: Abaris Books, 1979), p. 63.

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ments of the alleged unwillingness of the Aristotelians to understand his views were one of the recurrent figures of his rhetoric. As we find in his correspondence, Galileo and his supporters were often skeptical about the very possibility of establishing a dialogue with the philosophers.[4]

A historian or philosopher of science close to the position of the logical empiricists would say that these statements about the impossibility of communicating with the competitors represented a mere rhetorical strategy. The new philosophers *did not want to talk* to the Aristotelians. Strong relativists, on the other hand, would take the question of whether those statements of incommunicability were real or rhetorical to be beside the point. All that matters is that an impossibility of communication was claimed to be experienced by the members of a group.

The analysis of the phenomenon of incommensurability does not need to be caught between these two opposite positions. Without following either the rationalists in declaring incommensurability taboo, or the relativists in taking it as an axiom, we may take a *diachronic* approach and analyze its *emergence* in relation to the internal structure, external boundaries, and relative power or status of the socio-professional groups involved in the non-dialogue.

The role of incommensurability in the process of scientific change may be approached through what I call a "Darwinian metaphor" derived from an homology I perceive between Kuhn's concept of paradigm and Darwin's notion of species. Both Kuhn's paradigm and Darwin's species refer to *populations* of individuals who interbreed either sexually (in Darwin's case) or intellectually (in Kuhn's case).[5] Consequently, the barrier of sterility among species observed by Darwin could be compared to the incommensurability Kuhn has perceived among competing paradigms. In the same way that the barrier of sterility is an anti-swamping device which prevents the characters of the new species from being absorbed back into the old one, incommensurability could be seen as a form of intellectual sterility — as the impossibility of breeding intellectually.

According to this Darwinian metaphor, incommensurability would be *necessarily* related to the conceptual speciation of a new paradigm. Then, as among natural species, the competition between scientific paradigms would be mediated by something equivalent to natural selection: the reward system of science. Therefore, competing paradigms do not need to engage in a fully constructive dialogue during a process of theory choice. To be dropped, a

[4]G. Galilei, *Opere*, A. Favaro (ed.) (Florence: Giunta, 1890–1909), Vol. X, pp. 498, 499, 503–504; Vol. XI, p. 47; Vol. V, p. 231. Hereafter referred to as *GO*.

[5]The analogy between species and paradigm can be pushed further. In fact, Darwin's notion of species as an interbreeding population differs from previous views of species as defined by a set of morphological attributes in ways that are reminiscent of the difference between Kuhn's notion of paradigm as referring to a community of scientists and older views of scientific theories as uninterpreted logical systems, as proposed by the logical empiricists.

theory does not need to be falsified or a research program superseded. Like species that die off not because they are extinguished by others but because they do not fit the environment any longer, paradigms can come to an end not because they are refuted but because their worth is no longer valued within their reward system. Similarly, as species do not need to compete directly with other species within a limited portion of the environment but can migrate (or find themselves) in a fairly safe ecological niche, scientific paradigms can also develop undisturbed by competition if they manage to get into a fairly isolated area of the reward system. In short, the very idea of theory *choice* is problematized by the Darwinian interpretation of incommensurability.

Therefore, while incommensurability may be perceived as a problem if it is approached as an effect of the linguistic structures of the competing theories, the diachronical analysis of its emergence may offer important clues about how paradigms develop *out of* previous ones.

II. Socio-professional Identities and Communication Breakdowns

But if the Darwinian metaphor suggests a role for incommensurability in the process of paradigm-speciation, it is unable to account for many of its complexities. For instance, whereas in a process of biological change sterility intervenes sooner or later, the modalities of the emergence of incommensurability during the process of scientific change do not seem to be determined by the paradigm's "genotype" but rather are context-dependent. In the non-dialogue between Galileo and the Aristotelians on buoyancy, the inability to communicate was moralistically blamed by Galileo on the interlocutors' unwillingness to engage in a constructive dialogue. In other cases, we find that one side stated authoritarianly that it did not need/want to talk to the other.[6] Also, we encounter often a lack of symmetry in statements of incommensurability. While sterility (or incommensurability according to Kuhn) works both ways, the history of science indicates that sometimes one group claimed to be unable to understand the other, but not vice versa. In the case of the debate on buoyancy, Galileo claimed that his Aristotelian interlocutors did not understand his Archimedean treatment of buoyancy because they were mathematically illiterate. In contrast, he boasted a perfect grasp of Aristotelian philosophy.[7]

Also, the application of the Darwinian metaphor to the process of scientific change exposes certain tensions in Kuhn's notion of paradigm. Historical cases of scientific change indicate that the breakdown of communication does not need to be directly caused by the different linguistic structures of the competing

[6] *GO*, Vol. IV, pp. 49, 467; Vol. X, pp. 503–504; Vol. V, p 231.
[7] *GO*, Vol. IV, pp. 31–32, 50, 124–125.

theories. Rather, it is often associated with instances of trespassing professional or disciplinary boundaries and violating socio-professional hierarchies. This suggests that although Kuhn presents his notion of paradigm as integrating both the conceptual and sociological dimensions of scientific activity, he actually privileges its linguistic and conceptual dimensions in his interpretation of incommensurability. In this case, "paradigm" does not denote a "species of practitioners" but something quite close to his earlier notion of "conceptual scheme" as presented in *The Copernican Revolution*.[8]

For instance, the breakdown of communication between Galileo and the Aristotelian philosophers during the dispute on buoyancy was also precipitated by the disciplinary hierarchy subordinating mathematics to philosophy that framed that debate. As expressed by one of the Aristotelians, Galileo's arguments could be dismissed *a priori* on grounds that Galileo, a mathematician, could not put forward interpretations about phenomena that fell in the philosophers' domain without being one of them. On the other hand, we find instances in which communication was maintained across radically different positions when the practitioners shared comparable socio-professional identity. For instance, Kepler (a Copernican), Magini (a Ptolemaic), and Tycho (a Tychonic) — all technical astronomers — were able to sustain a long dialogue although their work presented or reflected radically different cosmologies.[9]

Further evidence for the importance of socio-professional identities in regulating communication between scientific practioners comes from an analysis of the rhetorical strategies of non-dialogue adopted by the opposing parties in case of cross-disciplinary disputes. The epideiectic rhetoric utilized by Galileo in his *Dialogue on the Two Chief World Systems* is a good example of one such strategy.[10] Despite his declared purpose of convincing the Aristotelians of the truth of his views, Galileo did exactly the opposite. He assumed a sympathetic audience — one of "free thinkers" rather than of Scholastics — and made fun of his competitors by representing them through an unrealistically simpleminded and dogmatic straw-man (Simplicio) who was systematically ridiculed by the Galilean champions (Sagredo and Salviati). The *Dialogo*

[8]T. S. Kuhn, *The Copernican Revolution* (Cambridge, Mass.: Harvard University Press, 1957), pp. 25–26, 36–37, 64–66, 74–77, 212–213, 261–262.

[9]A. Favaro (ed.), *Carteggio inedito di Ticone Brahe, Giovanni Keplero e di altri astronomi e matematici dei secoli XVI e XVII con Giovanni Antonio Magini* (Bologna: Zanichelli, 1886).

[10]Epideiectic or ceremonial rhetoric assumes a basic agreement between the values of the speaker and those of his/her audience. Examples of this rhetoric could be the *éloges* for a recently dead academician. The rhetoretician narrates the late academician's life as an emblem of the academy's corporate values so as to reinforce the corporate values of that group. See B. Vickers, 'Epideiectic Rhetoric in Galileo's *Dialogo*', *Annali dell'Istituto e Museo di Storia della Scienza di Firenze* **8** (1983), 69–101, and J. W. O'Malley, *Praise and Blame in Renaissance Rome* (Durham: Duke University Press, 1979). Although D. Outram does not use epideiectic rhetoric as one of the interpretive categories of her 'The Language of Natural Power: The *Eloges* of Georges Cuvier and the Public Language of Nineteenth Century Science', *History of Science* **16** (1978), 153–178, her analysis is relevant to this point.

turned out to be a sort of insiders' joke at the expense of the Aristotelians. Its function was to make readers who were already sympathetic to Galileo and who identified themselves with Sagredo or Salviati laugh with them at the Aristotelians. The *Dialogo* was not meant to be a dialogue. It was not meant to convince the "other", but rather to confirm and preserve the identity of the "one".

Commensurable rhetorical strategies for maintaining the cohesion of one's group are found in the texts produced during the dispute on buoyancy of 1611–1613. Looking at the Aristotelians' response to Galileo's 1612 *Discourse on Bodies in Water* one is puzzled by the philosophers' quantitatively overwhelming and amazingly repetitive refutations of Galileo's thesis. These texts seem to represent more an hysterical reaction to the "other" than an attempt to establish a rational dialogue with the competitor. Castelli — whom Galileo put in charge of responding to his critics — noticed quite perceptively that the function of those prolix texts was to reassure the supporters of the Aristotelians that Galileo had been attended to. As he put it, the view of so many printed characters must have quenched their anxieties.[11] As in the case of Galileo's *Dialogo*, the texts of the Aristotelians were not aimed at convincing the adversary. They were, instead, forms of non-dialogue whose function was to maintain the cohesion — this time by reducing the anxieties — of the group to which the writers belonged.

I am not saying that claims of incommunicability, rhetorical strategies of non-dialogue, and the phenomenon of linguistic incommensurability amount to the same thing. Nor do I claim that differences in socio-professional identity alone can determine the possibility of communication or the emergence of incommensurability. Rather, as I hope to show by the end of this paper, such claims, strategies, and linguistic phenomena are related in that they all play a crucial role in the formation and preservation of a group's cohesion and socio-professional identity. In fact, although incommensurability is a very specific phenomenon tied to the linguistic dimensions of competing theories, the *development* of incommensurability depends not only on the theories' linguistic dimensions, but on the various processes through which socio-professional identities are formed around theories, and on the way the formation of those identities allows, in turn, for the further articulation of those theories.

In order to understand the link between the specifically linguistic phenomenon of incommensurability and the processes through which socio-professional identities are shaped and maintained, we need to appropriate some of the work of philosophers, cultural anthropologists and sociologists of knowledge. For instance, Lakatos analyzed the responses of a group of mathematicians to

[11] *GO*, Vol. IV, p. 462.

anomalies to their paradigm discovered by mathematicians belonging to a competing group.[12] He classified some of those responses as "monster-barring strategies". Lakatos' anthropological insight suggests that anomalies (or novelties) can be perceived as expressions of the "other". Expanding on Lakatos, Bloor has interpreted the pattern of mathematicians' responses to conceptual novelties in terms of Mary Douglas' "grid and group" model.[13] In doing so, he has extended Lakatos' "conceptual other" into a "social other" and related a given community response to the "other" to the structure of that community. My interpretation of the emergence and role of incommensurability in the process of scientific change evolves from these studies. But differently from Bloor, I extend the analysis of a group's response to the "other" so as to cover also the genesis of the phenomenon of incommensurability.

III. Philosophers and Mathematicians

The interpretation of the emergence of incommensurability as proposed here relates scientific and social change by indicating that the legitimation of radically new theories or world views may require revolutions in the social hierarchy of disciplines and the emergence of new socio-professional groups. The scientific revolution is a good example of this process. As perceptively noticed by the protestant theologian Osiander in his preface to *De revolutionibus,* Copernicus' work could (and eventually did) trigger such a *double* revolution.[14] The breakdown of communication between Galileo and the Aristotelians on methodological and cosmological issues during the dispute on buoyancy should also be interpreted in the context of the disciplinary hierarchy characteristic of a scientific revolution which subordinated mathematics to philosophy.

The philosophical arguments used to justify this disciplinary hierarchy that was both cognitive and social at the same time relied on Aristotle's classifica-

[12]I. Lakatos, *Proofs and Refutations* (Cambridge: Cambridge University Press, 1976).

[13]D. Bloor, 'Polyhedra and the Abominations of Leviticus: Cognitive Styles in Mathematics', *British Journal for the History of Science* **11** (1978), 245–272; D. Bloor, *Wittgenstein: A Social Theory of Knowledge* (New York: Columbia University Press, 1983), especially 'Strangers and anomalies', pp. 138–159. For M. Douglas' early views on the relationship between the response to the "other" and the social taxonomy of the respondent group, see *Purity and Danger* (London: Routledge & Kegan Paul, 1966). For the "grid-and-group" model, see her *Natural Symbols* (New York: Pantheon, 1970), and *Cultural Bias* (London: Royal Anthropological Institute, 1978).

[14]"There have already been widespread reports about the novel hypotheses of this work, which declares that the earth moves whereas the sun is at rest in the centre of the universe. Hence, certain scholars, I have no doubt, are deeply offended and believe that the liberal arts, which were established long ago on a sound basis, should not be thrown into confusion'. N. Copernicus, *On the Revolutions,* J. Dobrzycki (ed.) and E. Rosen (trans.) *Complete Works* (Warsaw–Cracow: Polish Scientific Publishers, 1978), Vol. II, p. xvi.

tion of disciplines.[15] To Aristotle and his followers, mathematical demonstrations were necessary demonstrations only when they were *not* applied to material entities. The truth of a theorem could not be transfered from the domain of mathematics to that of physics — from immaterial to material entities. Similarly, the mathematicians were not supposed to deal with the physical causes of motion or, more in general, of change. Statics and kinematics, rather than dynamics, were the proper domain of the mathematician. Being an inherently abstract discipline, mathematics could not explain change. That required adequate *physical* principles which were beyond the jurisdiction of mathematics.[16] It was through philosophy that one could have access to those physical principles and study the *essential* aspects of natural phenomena. Instead, as the Aristotelians told Galileo,[17] mathematics — being alien to the "real" principles of the physical world — could only aspire to measure the quantities, that is, the *accidental* aspects of phenomena.[18]

According to the methodological boundaries entailed by this hierarchy, the philosophers developed qualitative cosmologies usually based on Aristotle's theory of the homocentric spheres. Technical astronomers, instead, were expected to produce quantitative predictions of planetary motions by means of various geometrical devices. The superior cognitive and social status of philosophy over technical astronomy was reflected in the philosophers' dismissal of the cognitive legitimacy of the mathematicians' method when this was applied to the explanation of physical processes. The mathematicians' geometrical constructions were perceived by the philosophers not as true representations of the cosmos, but as mere computational devices or, worse, as tricks.[19] As a result of the philosophers' disciplinary power, the mathematicians were *forced into* a sort of *nominalist* methodological position. The philosophers, instead,

[15]For the relation between the social and cognitive status of mathematics and philosophy in Italy before Galileo see M. Biagioli, 'The Social Status of Italian Mathematicians, 1450–1600', *History of Science* **27** (1989), 41–95.

[16]*GO*, Vol. IV, p. 423.

[17]*GO*, Vol. IV, p. 165, 389, 423; Vol. III, p. 255.

[18]On the sixteenth-century Italian debates on the cognitive status of mathematics, see P. Galluzzi, 'Il Platonismo del tardo Cinquecento e la filosofia di Galileo', *Ricerche sulla cultura dell'Italia moderna*, P. Zambelli (ed.) (Bari: Laterza, 1973), pp. 39–79; A. Crombie, 'Mathematics and Platonism in the Sixteenth-century Italian Universities and the Jesuit Educational Policies', *Prismata*, Y. Maeyama and W. G. Saltzer (eds) (Wiesbaden, 1977); P. Dear, 'Jesuit Mathematical Science and the Reconstitution of Experience in the Early Seventeenth Century', *Studies in History and Philosophy of Science* **18** (1987), 133–175; G. C. Giacobbe, 'Il *Commentarium de certitudine mathematicarum disciplinarum* di Alessandro Piccolomini', *Physis* **14** (1972), 162–193; 'Francesco Barozzi e la *Quaestio de certitudine mathematicarum*', *Physis* **14** (1972), 357–374; 'La riflessione metamatematica di Pietro Catena', *Physis* **15** (1973), 178–196; 'Epigoni del seicento della "quaestio de certitudine mathematicarum": Giuseppe Biancani', *Physis* **18** (1976), 5–40. On the debate on the cognitive status of mathematics in astonomy, see note 20 below.

[19]*GO*, Vol. IV, p. 49; Vol. III, p. 254.

were entitled to a *realist* position on cosmological matters.[20] This *a priori* dismissal of the mathematicians' claims to the physical reality of their mathematical hypotheses was also related to the breakdown of constructive dialogue between two disciplines: the philosophers *did not need to listen* to mathematicians. Given the hierarchical setting in which they operated, they were not obliged either to learn the mathematicians' language or to take seriously what the mathematicians put forward as their physical principles.

Copernicus rejected the mathematical nominalism imposed upon astronomers by the philosophers and upheld the cognitive legitimacy of mathematical realism. According to the Copernicans, the geometry of the heliocentric theory was a true representation of the cosmos and not a set of mathematical tricks. Also, not only did Copernicus and some of his followers embrace mathematical realism, but they also began to dismiss the language and method of the philosophers by claiming that mathematics was the only language in which astronomical matters *should* be discussed and judged.[21] This form of mathematical élitism, exemplified by Copernicus' "mathematics is for mathematicians", signified the inversion of the previously accepted rules of the game. Copernicus declared himself unwilling to listen to the philosophers' argument in the same way the philosophers had previously dismissed the mathematicians'. Rheticus followed suit by claiming that astronomy should be judged in mathematical courts only, while Galileo stated that philosophers *should not* criticize his arguments unless they understood mathematics.[22]

Disciplinary hierarchies and strategies of emancipation did not characterize the interaction between Copernicans and philosophers only, but they framed the dialogue between philosophers and practitioners of mixed mathematics in general. Tensions, arguments, and strategies quite analogous to those encountered between astronomers and philosophers emerged during the dispute on buoyancy. For instance, one of Galileo's adversaries in the dispute on buoyancy — Delle Colombe — attacked Galileo's theory of buoyancy with methodological arguments analogous to those he had previously employed in

[20]The debate on nominalism and realism in astronomy has often been structured around the critique of Duhem's overly clear-cut notions of "instrumentalism" and "realism" which he presented in *To Save the Phenomena* (Chicago: University of Chicago Press, 1969). For critiques of Duhem and further articulations of the issue see: G. E. R. Lloyd, 'Saving the Appearances', *Classical Quarterly* **28** (1978), 202–222; N. Jardine, 'The Forging of Modern Realism: Clavius and Kepler Against the Sceptics', *Studies in History and Philosophy of Science* **10** (1979), 141–173; N. Jardine, *The Birth of History and Philosophy of Science* (Cambridge: Cambridge University Press, 1984), pp. 225–257; N. Jardine, 'The Significance of the Copernican Orbs', *Journal for History of Astronomy* **13** (1982), 168–194; R. S. Westman, 'The Astronomer's Role in the Sixteenth Century: A Preliminary Study', *History of Science* **18** (1980), 105–147; R. S. Westman, 'Kepler's theory of hypothesis and the "realist dilemma" ', *Studies in the History and Philosophy of Science* **3** (1972), 233–264.

[21]N. Copernicus, *op. cit.*, Vol. II, p. 5.

[22]J. Rheticus, *Narratio prima*, in: E. Rosen (ed.) *Three Copernican Treatises* (New York: Dover, 1939), p. 139; *GO*, Vol. IV, p. 467.

his critique of Galileo's work on the new star of 1604 and of the cosmological implications of his astronomical discoveries of 1610.[23] Similarly, Di Grazia, another of Galileo's opponents, tried to dismiss the legitimacy of his treatment of buoyancy by arguing against the applicability of the mathematical method to the explanation of *physical* phenomena — an argument previously deployed by philosophers against astronomers.[24]

In short, both the Copernican hypothesis and Galileo's mathematical treatment of buoyancy represented instances of the mathematicians' invasion of the philosophers' domain and of the attempt to upset received disciplinary hierarchies. As such, the debates they triggered were characterized by comparable types of non-communicative behaviours, *a priori* dismissals of the other's positions, and attempts to enforce or change the received rules of the game rather than to engage in a constructive dialogue.

However, these invasions and the communication breakdowns that ensued were not just the result of power (or survival) struggles among disciplines or species of scientific practitioners. The mathematicians did not have the disciplinary status and power to invade the philosophers with just any pretext. They needed very good arguments. The Copernican astronomy and the Archimedean theory of buoyancy were two of them. In fact, in contrast to the proliferation of not-always-coherent mathematical hypotheses that characterized Ptolemaic astronomy at the beginning of the sixteenth century, Copernicus offered a coherent and *professionally unifying* world-view. He offered the mathematicians a 'dogma' around which *both* a coherent astronomy *and* a stronger socio-professional identity could be developed. Copernicans could think of themselves as philosophers and have a chance to be taken seriously. Ptolemaics could not.

Maybe the Archimedean theory of buoyancy did not have the same "emancipatory power" of Copernicanism, but Galileo began to turn Archimedes' hydro*statics* into the basis of a *dynamics*. By doing so, he began to move from the proper domain of mathematicians into the domain of the philosophers. As Galileo's adversaries were quick to notice, Galileo's theory of buoyancy was a bit of a Trojan Horse through which he was trying to invade the domain of the philosophers.[25] Therefore, if Copernicus offered the mathematicians a chance to displace the philosophers from the superlunary sphere, Galileo's theory of buoyancy could have started the mathematicians' invasion of the sublunary sphere. Similar armies, weapons, and tactics were facing each other on different fields.

[23] *GO*, Vol. III, pp. 254–255; Vol. IV, p. 352.
[24] *GO*, Vol. IV, p. 385.
[25] *Ibid.*, p. 156.

IV. The Dispute on Buoyancy

Galileo began his career as a university professor of mathematics, first at Pisa and then at Padua. The low status (and stipends) of mathematics professors indicates that the university represented the institutionalization of the disciplinary hierarchy discussed above.[26] From Padua, Galileo migrated to a much different reward system: the Medici court. In this new ecological niche his status would no longer be defined by the Aristotelian hierarchy of liberal disciplines, as in the university reward system, but rather by the Grand Duke's favour. At court, Galileo the mathematician could speciate into Galileo the philosopher.

However, his migration from one reward system to another was by no means a standard move. On the contrary, it was made possible by his skilful presentation of the spectacular astronomical discoveries of 1610 within the discourse of the Medici dynastic myths.[27] It was by capitalizing on his quick rise to European fame and on the remarkable fit between his discoveries and the Medici dynastic myths, that Galileo was able to obtain the title of *Philosopher* and Mathematician of the Grand Duke.

In a social context in which cognitive credibility was closely related to social status, Galileo found in Cosimo II the great patron he needed to ennoble himself and gain cognitive legitimation for his discoveries and mathematical method.[28] Although Galileo's professional role was not the same as the Aristotelian philosophers' (he did not teach philosophy at the university), he obtained through the patronage relation with the Medici a title and the related social legitimation that allowed him to argue with the philosophers *inter pares*.[29]

Such an opportunity came soon. During the summer of 1611, a discussion on the nature of cold took place at Salviati's.[30] Di Grazia and Coresio — two Aristotelians who taught at the University of Pisa — claimed that ice was condensed water because it was of the nature of cold to condense substances.

[26]M. Biagioli, *op. cit.*, pp. 42–56.

[27]M. Biagioli, 'Galileo the Emblem-Maker', forthcoming in *Isis* **81** (1990).

[28]M. Biagioli, 'Galileo's System of Patronage', forthcoming in *History of Science* **28** (1990).

[29]Actually, Galileo presented his performance in philosophical debates as the very "test" of his philosophical knowledge and abilities, *GO*, Vol. X, p. 353.

[30]The debate is reconstructed in S. Drake, *Galileo Studies* (Ann Arbor: Michigan University Press, 1970), pp. 159–176; G. Galilei, *Discourse of Bodies in Water*, S. Drake (ed.) (Urbana: University of Illinois Press, 1960), pp. ix–xxvi. More information is included in the introduction to Drake's new English translation of the *Discourse* in his Galileian-style dialogue *Cause, Experiment and Science* (Chicago: University of Chicago Press, 1981). The conceptual dimensions of the dispute have been analyzed in W. Shea, 'Galileo's Discourse on Floating Bodies: Archimedean and Aristotelian Elements', *Actes XII Congrès International d'Histoire des Sciences, Paris, 1968* (Paris, 1971), Tome IV, pp. 149–153; W. Shea, *Galileo's Intellectual Revolution* (New York: Science History Publications, 1977), pp. 14–48; W. Wallace, *Galileo and His Sources* (Princeton: Princeton University Press, 1984), pp. 284–288. For an extensive contextual analysis of the dispute, see M. Biagioli, 'Anatomy of a Court Dispute', forthcoming.

Galileo opposed them by claiming that ice was rarefied water because it floated on it. The philosophers replied by saying that ice did not float because it was rarefied water but because of its relatively flat and thin shape.

More precisely, the Aristotelians maintained that the elemental make-up of substances was the fundamental cause (*per se* or *simpliciter*) of their floating or sinking in water, as well as of any other natural movement within the sublunary sphere. However, in certain instances, like with ice or with the very thin lead plate that Aristotle had observed floating on water, shape could become the accidental cause (*secundum quid*) of buoyancy.[31] Following Archimedes' *On Floating Bodies,* Galileo denied that the shape of an object had anything to do with buoyancy which, instead, he claimed to be a direct result of the difference between the density of the body and of the surrounding medium. All that shape influenced was the speed at which the body would sink or surface in the medium.[32] The opposition between Aristotle's element-based thinking and Galileo's mathematical method was already legible in these initial exchanges.

A few days later, the Aristotelians' ranks were swelled by a long-time opponent of Galileo's — the Florentine philosopher Lodovico delle Colombe.[33] The newcomer was able to produce an experiment which seemed to refute Galileo's view on buoyancy. Delle Colombe showed that a sphere of ebony (a material with a specific weight greater than that of water) would sink if placed on water, while a thin piece of the same material would remain afloat. From this he concluded that, contrary to Galileo, buoyancy was not a matter of difference in specific weights, but depended on shape.

The evidence put forward by Delle Colombe was based on the phenomenon of surface tension, which neither he nor Galileo understood. The entire debate that followed revolved about the contendants' lack of knowledge regarding this phenomenon. Without such a lack, the Aristotelians' position would have been refuted (at least experimentally) by Galileo. Instead, in this context, Delle Colombe's experiment produced a quite conspicuous crucial anomaly to the Archimedeo–Galileian theory of buoyancy.

It quickly became apparent that, given the incompatibility in the methodologies and experimental conditions invoked by the two parties, he who could set the rules of the game would win. Consequently, the dispute turned almost totally into a confrontation about the very rules of the game. The deadlock was particularly severe because both parties could claim to be philosophers. In a traditional setting, the Pisan Aristotelians could have silenced Galileo by invoking traditional disciplinary boundaries and hierarchies, but those arguments were no longer final now that Galileo could legitimately use the title of

[31] *GO*, Vol. IV, pp. 43, 45, 174, 212, 337, 403, 420–421.
[32] *Ibid.*, pp. 34, 45, 65–67, 318.
[33] *Ibid.*, pp. 34–35.

philosopher — at least within the Medici reward system. In this setting, both parties had comparable power leverages. And their levers had a common fulcrum: the Grand Duke.

The deadlock generated by Delle Colombe's experience triggered a range of behavioural and textual strategies. For instance, Galileo was quick to switch from talking of bodies *on* water to considering the behaviour of bodies *in* water, hoping to avoid the problems posed by surface tension. The problem, as he saw it with new eyes, was to establish whether or not bodies emerged from the water once they were placed at the bottom of the container. If Delle Colombe insisted on experimenting with bodies on water, that was also fine with Galileo, provided that he experimented with *wet* bodies. The *ad hocness* of Galileo's move did not go unnoticed, and the Aristotelians insisted on a literal interpretation of Galileo's early statements about buoyancy concerning bodies *on* water.[34]

Two public experimental sessions were agreed upon, but — confirming the two parties' difficulties in agreeing on an experimental setting — no experiment was performed at either meeting. The first session was deserted by Delle Colombe who may have thought that the two judges, Neri and Arrighetti, were better friends of Galileo's than of his and, consequently, may have ruled out the relevance of his powerful but isolated anomaly. A second meeting was scheduled at Salviati's, but this time it was Galileo who refused to participate, claiming that — as suggested by the Grand Duke — he would put his views in print.[35] Apparently, the Grand Duke did not like the idea of his philosopher being involved in noisy disputes. As a result of the Grand Duke's intervention, the dispute moved away from oral arguments and public meetings to texts and courtly settings.

A new dispute on buoyancy took place at court in the fall of 1611 during the visit to Florence of cardinals Gonzaga and Barberini. Galileo, the court philosopher, was confronted by Papazzoni, the leading Pisan philosopher. Apparently, the spectacle was enjoyable, but opinions about the outcome seemed to fall along party lines.[36] Delle Colombe and his fellow Aristotelians were not granted access to the courtly phase of the dispute, and when Galileo's *Discourse on Bodies in Water* (note the "*in*") came out in the late spring of 1612, they were surprised to find that their names were not mentioned in the text.[37]

In fact, not only did Galileo use the Grand Duke's firm advice to put his

[34] *Ibid.*, pp. 28, 34–35, 44, 96, 120, 162, 319, 337, 403.
[35] *Ibid.*, pp. 30, 34–35.
[36] *GO*, Vol. IV, pp. 331; Vol. XI, pp. 304–305, 317–319, 325–326, 338–339, 453–455.
[37] It is also unclear how energetically Papazzoni defended their positions during the dispute at court, given the fact that he had just obtained a chair at Pisa largely thanks to Galileo's patronage. Papazzoni was vocal about his debts to Galileo in a few letters, *GO*, Vol. XI, p. 59, 63. See also *ibid.*, p. 58.

views in print as an excuse to pull out of a deadlocked dispute, but he also tried — with little success — to present his book as a systematic treatise on buoyancy rather than as a polemic anti-Aristotelian pamphlet tied to the dispute. In a way, Galileo tried to present his patron's firm advice to drop messy disputes as a waiver of his responsibility to answer his non-courtly opponents.[38] Rather than finding an agreement with his opponents, Galileo was able to ignore them by migrating to a sub-region of the Medici reward system where they could not reach him. Or so he thought.

The Aristotelians understood well that Galileo was now quite out of their reach and that the favour of the Medici would have decided the dispute. Being unable to carry their argument in person into the court, they decided to reach both Galileo and the Medici through texts. Four books by Delle Colombe, Giorgio Coresio, Vincenzo Di Grazia, and the Anonymous Academician were published in rapid succession in response to Galileo's *Discourse*. They were all dedicated to members of the Medici family, from Cosimo's wife and brothers, to Galileo's long-time enemy — Giovanni de' Medici.[39]

V. Anatomy of a Deadlock

The implications of the methodological differences that had already surfaced during the early phases of the dispute were articulated further in Galileo's *Discourse* and in the four responses by the Aristotelians. Delle Colombe's experiment and the phenomenon of surface tension on which it rested were still at centre stage, but they were now linked to other radical disagreements about the structure of matter and about the very notions of causality and evidence.

In the *Discourse* Galileo announced a "discovery" that turned Delle Colombe's anomaly into a confirmation of the Archimedean theory of buoyancy. If you look carefully at the thin piece of ebony floating on the water — Galileo argued — you will see that the object is not at the same level as the water surface but a bit lower. It is as if small banks (*arginetti*) prevented the water from closing itself over the object (Fig. 1). Therefore, what floated was not *just* the piece of ebony, but the piece of ebony *and* the air contained by the ebony at the bottom and by the small banks to the sides. And, being the combined specific weight of ebony and air lower than that of water, the ebony–air composite floated according to Archimedean principles.[40]

The discovery of the small banks helped Galileo support his previous claim that buoyancy was a matter of bodies *in* and not *on* water. Properly speaking,

[38] *GO*, Vol. IV, pp. 30, 34–35, 65.

[39] L. Delle Colombe, *Discorso apologetico d'intorno al discorso di Galileo Galilei* (Florence: Pignoni, 1612); *Considerazioni di Accademico Ignoto sopra il Discorso del Sig. Galilei* (Pisa: Boschetti, 1612); G. Coresio, *Operetta intorno al galleggiare de' corpi solidi* (Florence: Sermartelli, 1612); V. Di Grazia, *Considerazioni sopra in Discorso di Galileo Galilei* (Florence: Pignoni, 1613). All four works are reprinted in *GO*, Vol. IV.

[40] *GO*, Vol. IV, pp. 97–101.

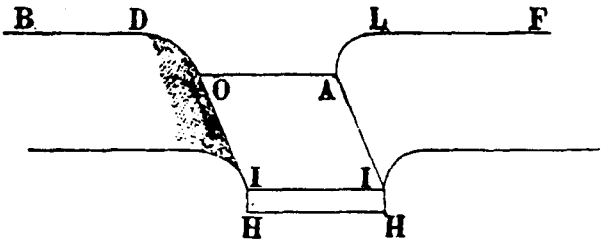

Fig. 1. According to Galileo, the ebony plate does not sink because the specific weight of the composite body constituted by the ebony plate HIOAIH and by the air volume included between the water surface BDLF and the surface of the plate IOAI is less than that of water. The curved lines DO and AL are the arginetti. From *GO*, Vol. IV, p. 98.

he argued, the piece of ebony was *in water*, for it had sunk below the *continuazione*, that is, the geometrical line representing the water surface previous to the laying of the ebony on it. To Galileo, the fact that the ebony had not actually cut the water surface was irrelevant.

This indicates the incompatible meanings of *in* according to the two parties. To Galileo, the water surface (meaning the "skin" of the water) was not a crucial item. What counted was the *geometrical* dimensions of the phenomenon. Contrary to Galileo, the Aristotelians tried to explain buoyancy not in terms of geometrically measurable volumes but through elemental properties. Therefore, to them the "skin" of the water (rather than the geometrical line marking the initial water *level*) was the line that mattered — the demarcation between *in* and *on*. It was the boundary between two elements, and it was there that buoyancy was determined. Galileo's lines were geometrical, those deemed crucial by his adversaries were boundaries between elements.[41]

Although Galileo claimed that the discovery of the small banks sunk Delle Colombe's "crucial experiment", he failed to give an explanation for the very existence of the small banks. When pressed, he took a positivist position: whatever the cause of the banks may be, they are evidently there, and they make the piece of ebony float according to Archimedes' principles.[42] Galileo's reluctance to offer an explanation for the small banks may be related to his view of the structure of matter. Thinking of water as made up of atoms, Galileo could not understand why water behaved differently at the surface and in its interior. Also, he could not admit that the shape of the body had anything to do with the phenomenon of the small banks, because that would have supported the Aristotelians' views. Therefore — with an argument symmetrical to his interpretation of the failure of pumps to bring water up

[41] *Ibid.*, pp. 28, 162, 337, 403, 405.

[42] Galileo did not explain the small banks but bluntly stated that 'e pur e così' (*ibid.*, p. 166), or that 'Che poi questi argini aquei non si rompino, scorrendo l'acqua ad ingombrar la detta buca e cavità, io poco mi curerò' (*ibid.*, p. 301).

more than ten metres — he suggested that the small banks were caused by the air that, by adhering to the piece of sinking ebony, was pulled down with it.[43]

Atomism was not an hypothesis Galileo could compromise on because of the role it played in his view of motion as presented in the *Discourse*. Trying to move from a statics to a dynamics of buoyancy (and of sublunary motion in general), Galileo strove to identify the causes that made a body move through a material medium. He argued that an infinitesimal *momento* could move a body of any bulk, provided that it were in equilibrium. Consequently, the assumption of the atomistic structure of matter was crucially important to Galileo because an infinitesimal *momento* would have been ineffectual unless the fluid surrounding the body were made up of free-moving atoms. The only effect of a medium made up of atoms would have been to add some virtual bulk to the body. Although the infinitesimal *momento* would have had to displace some atoms of the medium together with the body, it would not have to confront any other type of resistance in the medium. As Galileo told the Aristotelians, a body sinking in water did not *cut* anything, it did not have to defeat any resistance. Water was not a sort of shield the sinking body had to penetrate.[44] The resistance of the medium influenced the speed of the body, but did not determine its buoyancy.[45]

The Aristotelians were not impressed by Galileo's refutation of Delle Colombe based on the discovery of the small banks and argued that Galileo had failed to explain what the small banks were about.[46] Consequently, they dismissed Galileo's attempt to see in the small banks the proof that buoyancy was something that happened *in* water and insisted that buoyancy was a matter of a body's resting *on* the water surface.

Behind their rejection of Galileo's interpretation of the small banks and geometrization of the water surface, we find the Aristotelians' defence of some of the crucial elements of their natural philosophy. They understood the symbiotic relation between Galileo's mathematical theory of buoyancy and his

[43]Such a peculiar interpretation of the formation of the small banks was a mirror image of his explanation of the "breaking" of a water column pumped up from its initial level for more than ten metres. In fact, he said explicitly that the sinking following the thin piece of ebony getting wet was caused by the water "cutting" the contact between the ebony and the air above it (*ibid.*, p. 111). Like the "breaking" of a water column, the sinking of the piece of ebony was the result of the breakdown of the *horror vacui*. The only difference from the case of the water pump in which the water column was "cut" by a "blade of air", was that here a column of air was cut by a "blade of water". Galileo may have perceived pumping and buoyancy as different aspects of the same scenario involving the displacement of two differently dense bodies into each other. The explanation of the behaviour of a body (water) being *sucked up* into a less dense body (air) was probably seen by Galileo as analogous to that of a less dense body (air) being *sucked down* into a denser body (water). The weight of the ebony could have been perceived as playing the role of the pump. In fact, if the body was too heavy (or the pump too strong), the column of either air or water would break down (or up).

[44]*Ibid.*, pp. 50, 86, 92, 106.

[45]*Ibid.*, pp. 34, 44–45.

[46]*Ibid.*, pp. 163, 166, 170, 172, 213, 335, 337, 416.

atomism, and they also realized that Galileo's view of buoyancy could be extended to cover sublunar motion in general. Therefore, in attacking Galileo's atomistic view of matter they were trying to refute his entire theory of motion and save theirs. In fact, the notion of a medium with infinitesimal resistance would have refuted their theory of motion based on the existence — at least in the sublunary sphere — of a *finite* resistance to motion. If Galileo's dynamics of buoyancy necessitated an infinitesimally resistant medium, the Aristotelians needed a medium with finite resistance to maintain theirs.[47]

Therefore, the differences in the two parties' positions were not limited to a few disjunct issues, but were connected into two incommensurable systems. The meaning of "in" and "on" referred back to different methodological assumptions which, in turn, reflected contrasting views about the structure of matter which, in turn, were related to the explanation of motion and, ultimately, to the cosmology behind it.

Given the deadlock in the interpretation of the phenomena, it is not surprising to find that the two parties tried to dismiss each other's method altogether. For instance, Galileo attacked the Aristotelians' classification of causes:

> there is only one, true, and proper cause of buoyancy — the one known to me and to others. Distinctions such as *per se* or *per accidens, proprie vel improprie, absolute vel respective* cannot be applied to it. Those distinctions are brought in only to help those who cannot grasp the true, proper, and immediate causes of the philosophical problems they are confronting.[48]

Symmetrically, Di Grazia claimed that Galileo's method inverted the natural relationship between reason and empirical evidence:

> he wants to demonstrate mathematically those things that fall within the domain of the senses... And, inversely, he insists on using the senses to explain those things that can hardly, if at all, be experienced by the senses, as with the irregularities of the moon's surface, the sunspots, and a thousand more things like that. *He should do the opposite.* It is superfluous to argue about things that can be directly grasped through experience. Instead, it is in those cases in which sensory experience is inadequate that we need to correct and help it through reason.[49]

More frequently, Galileo's adversaries attacked the legitimacy of mathematical method when applied to the explanation of *physical* phenomena with

[47]Moreover, the Aristotelians had to argue for the existence of some additional resistance at the boundary between water and air in order to explain the behaviour of the thin piece of ebony which floated on the water surface but did not emerge once it was placed in the medium. They did so by relying on the teleological character of their cosmology. In fact, surface tension could be easily related to the water element's "place" and to its boundary. The higher resistance offered by the water surface could be seen as a natural effect of the tendency of the water element not to be displaced from its natural place, *ibid.*, pp. 329–330, 333, 418, 434.

[48]*Ibid.*, p. 299.

[49]*Ibid.*, p. 436. (Emphasis mine.)

arguments strikingly similar to those used by the philosophers against mathematical astronomers with philosophical ambitions.[50] In other instances, they accused Galileo of *petitio principii*, an accusation whose source is to be found, again, in the received hierarchy among disciplines.[51] In fact, the philosophers claimed they could not find in the *Discourse* the *physical* principles at the basis of Galileo's demonstrations because they did not want to recognize as *physical* the principles, much different from theirs, that Galileo had put foward quite clearly.

The mutual accusations were not limited to method. Both parties tried to attack each other's credibility by questioning the other's professional competence. Galileo claimed that his adversaries were perfectly ignorant of mathematics and unable to understand his arguments. Symmetrically, the philosophers questioned Galileo's competence in interpreting Aristotle. However; they could not claim Galileo's ignorance too loudly because in the *Discourse* he had shown that he was quite comfortable playing with Aristotelian philosophy.[52] All they could say was that he was heretical in his interpretations.[53] Instead, in general, the philosophers did not respond to Galileo's attack on their mathematical illiteracy. It seems they did not want to recognize it as an issue by answering it.[54]

But, whatever they may have thought of each other, both Galileo and the Aristotelians were legitimate philosophers within the Grand Duchy of Tuscany. Mutual accusations of methodological illegitimacy or personal incompetence were bound to remain ineffectual unless the Grand Duke endorsed them. Both parties seemed to understand this and developed different strategies to obtain enough power from Cosimo to *dismiss* (rather than dialogue with) the adversary.

In a draft of the *Discourse*, Galileo presented himself as Cosimo's scientific paladin in need of his King's support:

> Most Serene Lord, I have taken the trouble (as your Lordship has seen) to keep alive my true proposition, and along with it many others that follow therefrom, preserving it from the voracity of the falsehood overthrown and slain by me. I know not whether the adversaries will give me credit for the work thus accomplished, or whether they, finding themselves under a strict oath obliged to sustain religiously every decree of Aristotle (perhaps fearing that if disdained he might invoke to their destruction a great company of his most invincible heroes), have resolved to choke me off and exterminate me as a profaner of his sacred laws. In this they would imitate the inhabitants of the Isle of Pianto when, angered against Orlando, in recompense for his having liberated so many innocent virgins from the horrible

[50] *Ibid.*, pp. 165, 233, 352, 385, 389, 391, 423.
[51] *Ibid.*, pp. 163, 233, 386, 388, 430.
[52] *Ibid.*, pp. 31, 36, 42–43, 97–98, 124–125.
[53] *Ibid.*, pp. 420, 423, 426.
[54] *Ibid.*, p. 240.

> holocaust of the monster, they moved against him, lamenting their strange religion and vainly fearing the wrath of Proteus, terrified of submersion in the vast ocean. And indeed they would have succeeded had not he, impenetrable though naked to their arrows, behaved as does the bear toward small dogs that deafen him with vain and noisy barking. *Nor I, who am no Orlando, possess nothing impenetrable but the shield of truth; for the rest, naked and unarmed, I take refuge in the protection of Your Highness,* at whose mere glance must fall anybody who — out of his mind — imperiously attempts to mount assaults against reason.[55]

In this remarkable metaphor for the dispute and for Cosimo's power in controlling it, Galileo indicated that the only way out of the dispute rendered irrational by "those fanatics" was to be given the "power of impenetrability" by Cosimo so that — like the bear that ignores the puppies barking around it — he could dismiss the Aristotelians and walk away.

If Galileo stressed his *personal* link to Cosimo II, the philosophers stressed the *institutional* link between the *Studio Pisano* and the *house* of Medici. In presenting the *Considerazioni* of the Anonymous Academician to Maria Maddalena, the *Provveditore* of the Studio Pisano — Count Pannocchieschi d'Elci — felt obliged to endorse this critique of Galileo in the name of the Pisan academic community.[56]

Pannocchieschi d'Elci claimed that Aristotle — the greatest of the philosophers — was protected by the greatest of the ancient kings — Alexander the Great — and hoped that the Medici, as *nuovi Alessandri,* would continue to protect him. If, instead, the Medici decided to support Galileo:

> [the glory of Aristotle] would either decline or fall altogether because most students — full of youthful exuberance, anxious to find some doctrine to follow, or bored by the received philosophy — would orient themselves toward a doctrine that proposes new ideas — though less reliable ones — especially if these were perceived as accepted by the sovereigns.[57]

In a similar vein, the Anonymous Academician warned the Medici that:

> Could it be that many bright youths, curious to know many things and captured by the novelty of this doctrine, would abandon the straight and safe road of the peripatetic doctrine to adopt a different one that — full of curves — presents different interpretations of all the phenomena of the universe? *If this were to happen, the universities and the public schools would loose too many students, and the great teachers who have taken Aristotle as their guide and first master would be barely listened to.*[58]

The dispute on buoyancy did not end with a clear verdict. Galileo's international fame had increased during the dispute on buoyancy because of

[55] *Ibid.*, p. 51. English translation adapted from S. Drake, *Galileo at Work* (Chicago: University of Chicago Press, 1978), pp. 173–174. (Emphasis mine.) See also *GO*, Vol. IV, p. 31, for a similar argument.

[56] *GO*, Vol. IV, p. 147.

[57] *Ibid.*, p. 147.

[58] *Ibid.*, pp. 177–178. (Emphasis mine.)

the discovery and debate on the sunspots and Cosimo would have probably damaged his own image had he dropped him. Yet Cosimo could not rule against the Aristotelians either, for that would have undermined the credibility of Aristotle's doctrine and probably of the entire curriculum of the Studio Pisano. Cosimo was caught between an important personal patronage relationship with Galileo and an institutional link to the Studio Pisano.

Although Cosimo did not take a clear stand, we can infer that he implicitly supported Galileo, since the latter did not feel he had to answer the philosophers' critiques, but — quite insultingly — passed that task on to his disciple Castelli. And Castelli did not rush. His book came out only in 1615, four years after the beginning of the dispute.[59]

VI. Bilingualism in Context

Although Kuhn has addressed the role of age and level of professional initiation in the process of theory choice, his treatment of the phenomenon of incommensurability has been characterized by a strict linguistic approach. Instead, as we have seen above, not all the forms of non-communicative behaviour which emerged during the dispute on buoyancy were rooted in the linguistic dimensions of the competing paradigms but depended also on the two parties' attempts to shape or preserve their socio-professional identities.

Although in more recent analyses of incommensurability like "Commensurability, Comparability, Communicability"[60] or "Scientific Development and Lexical Change"[61] Kuhn has replaced "paradigm" with "lexical structure", he has maintained a strictly linguistic approach to the issue. He argues that the resolution of a communication breakdown because of an actual incommensurability between two discourses cannot be achieved through a successful translation, but rather through a learning of the other's language through a series of ostensions.

Siding with the structural linguists, Kuhn claims that a given linguistic category is defined in terms of the differences between it and those that surround it.[62] What we mean by "swan" depends also on what we mean by

[59]B. Castelli, *Risposta alle opposizioni del S. Lodovico delle Colombe e del S. Vincenzio di Grazia contro al trattato del Sig. Galileo Galilei...* (Florence: Giunti, 1615), reprinted in *GO*, Vol. IV, pp. 448–691.

[60]T. S. Kuhn, 'Commensurability, Comparability, Communicability', *PSA* 1982, Proceedings of the 1982 Biennial Meeting of the Philosophy of Science Association, P. D. Asquith and T. Nickles (eds) (East Lansing, Michigan: PSA, 1983), Vol. II, 669–688.

[61]T. S. Kuhn, 'Scientific Development and Lexical Change', The Thalheimer Lectures, Johns Hopkins University, 12–19 November 1984. (Unpublished manuscript.)

[62]F. de Saussure, *Cours de linguistique générale* (Paris: Payot, 1986), pp. 155–162; C. Lévi-Strauss, *The Savage Mind* (Chicago: University of Chicago Press, 1966), p. 115; T. S. Kuhn, 'Commensurability, Comparability, Communicability', pp. 680–682, and 'Second Thoughts on Paradigms', *The Essential Tension* (Chicago: University of Chicago Press, 1977), pp. 293–319. Kuhn's notion of grid resembles the network model of universals presented by Mary Hesse in *Structure of Scientific Inference* (Berkeley: University of California Press, 1974), pp. 45–73.

"duck" and on how "swan" differs from "duck". Once it is admitted that the relationship between a term and the object is constructed as a result of an array of *differences* between that term and object and the other terms and objects around them, it follows that the referent of a term cannot be established locally. Piecemeal translation would not do. Instead, one has to reconstruct the *entire* linguistic grid peculiar to that language.[63] And it may turn out that such a grid and the world view associated with it would not be fully homologous with that associated with the interpreter's native language. In that case, the interpreter would face linguistic incommensurability and complete translation would not be possible. For instance, how can we translate our "swan" — which we define also in terms of "duck" — into the language of a culture whose world does not contain ducks?

To sum up Kuhn's position, incommensurability is the result of non-homology between linguistic grids, which, in turn, reflects the differences between two cultures and their environments as those cultures know them. Although incommensurability precludes full translation of one language into the other, access to two incommensurable linguistic grids is still possible by learning the other language together with the world taxonomy associated with it. However, if bilingualism offers a way *around* incommensurability, it cannot resolve it. To be *bi*lingual does not mean to be *meta*lingual. Bilingualism makes one *aware* of incommensurability, but does not solve it.

Although I share Kuhn's views about the linguistic dimensions of incommensurability and about the impossibility of complete translation among incommensurable linguistic grids, I think he overestimates the possibilities for dialogue and theory evaluation offered by bilingualism. I will try to make this point by analyzing the implications of Galileo's claim that the dead-lock in the debate was caused by the Aristotelians not understanding him because of their ignorance of mathematics, while, instead, he could understand Aristotle perfectly.[64]

I do not see on what grounds we should expect a group to learn the language of its socio-professional competitors. Galileo's claim about the stubborn ignorance of the philosophers in mathematical matters reflects a specific socio-professional ethos. In a fashion that is reminiscent of his earlier attempts to define the rules of the game by setting the experimental and methodological standards, Galileo took for granted (actually or rhetorically) that the other group should share his cognitive ethos toward the production of *new* knowledge. As a result, he characterized the Aristotelians' ignorance of mathematics as unethical. He accused them of being viciously stubborn and unwilling to see the truth that stood in front of their eyes.

[63]T. S. Kuhn, 'Commensurability, Comparability, Communicability', pp. 673–675, 680–682.
[64]*GO*, Vol. IV, pp. 31–32, 65.

But Galileo was not alone in assuming a moralistic attitude. In fact, the Aristotelians attacked him for his intellectual narcissism, his "lust for novelty", and his attempted subversion of traditional disciplinary hierarchies.[65] These reciprocal moralistic accusations do not seem to have much to do with buoyancy. Rather, they reflect quite accurately the irreducible differences in the ethos and socio-professional identities of those who uttered them. Also, the pervasive use of moralistic (rather than "rational") arguments on both sides indicates the lack of dialogical alternatives. Moralism is there to defend dogmas, not to negotiate them. Moralism is a potential sign of incommensurability.

The incommensurability between Galileo and the philosophers was not limited to their views of the physical world, but it extended well into their own professional ethos. Although sixteenth-century Aristotelianism did not constitute a homogeneous philosophy, its practitioners shared a quite well defined socio-professional identity. Usually, they were university professors, went through a fairly homogeneous and fairly long professional training, and had a strong corporate identity both as members of an internally structured institution such as the university, and as keepers of a set of canonical texts.[66] Galileo saw them as members of a peculiar religious order.[67] The discovery of novelties was not one of the corporate duties for which they were trained and paid.[68] To use Mary Douglas' terminology, they were a high-grid/high-group culture.[69] Their corporate identity was well portrayed in the Anonymous Academician's "call to arms" to prevent Galileo's doctrine from entering the university:

> My fellow Peripatetics, it is no longer time for jokes. The honour and status of your prince is now threatened. With waving flags, the Author [Galileo] is boldly moving against the previously undefeated fortress of the Peripatetic doctrine. Although this type of argument has been deployed against it on other occasions but was eventually refuted and vanquished, nevertheless it is a much lauded military rule to control the enemies continuously to prevent them from increasing their confidence and power, especially when they are ingenious, ambitious, and subtle.[70]

[65] *Ibid.*, pp. 156, 335, and footnotes 57 and 58.

[66] C. B. Schmitt, *Aristotle and the Renaissance* (Cambridge: Harvard University Press, 1983), pp. 10–33; C. B. Schmitt, *The Aristotelean Tradition and Renaissance Universities* (London: Variorum, 1984); C. B. Schmitt, *Studies in Renaissance Philosophy and Science* (London: Variorum, 1981). See also the special issue dedicated to 'L'Aristotelisme au XVI[e] siècle' by *Les Etudes Philosophiques* **3** (1986), and L. Giard, 'Du Latin médiéval au pluriel des langues, le tournant de la Renaissance', *Histoire, Epistémologie, Langage* **6** (1984), 35–55.

[67] *GO*, Vol. IV, p. 51. See also note 55 above.

[68] Cremonini, answering the Inquisition, offered a clear statement of his corporate identity: 'Non posso ne' voglio retrattare le esposizioni d'Aristotile, poiche l'intendo così, *e son pagato per dichiararlo quanto l'intendo*, e nel facendo, sarei obbligato alla restituzione della mercede'. (Quoted in C. Schmitt, 'Cesare Cremonini, un aristotelico al tempo di Galilei', *The Aristotelean Tradition and Renaissance Universities*, chap. XI, p. 13.) (Emphasis mine.)

[69] M. Douglas, *Natural Symbols*, pp. 103–106.

[70] *GO*, Vol. IV, p. 177.

and that:

> I believe that in order to preserve the jurisdiction of this lady [philosophy] it would be enough that her confederates and followers — honouring their corporate duties — would help her destroy the warfare machine of the enemies and withstand this dangerous siege. Through a simple defence strategy and without driving the air back [a reference to Galileo's views on buoyancy], they will be able to preserve philosophy in her jurisdiction. Eventually, the air — lacking any firm stand and relying for its force only on foreign powers — will be forced to withdraw into its own region.[71]

In contrast to the Aristotelians, Galileo was not a "confederate". He obtained his title of philosopher through court patronage rather than through a regular training in philosophy. He did not undergo a standard professional initiation. As the Anonymous Academician put it, Galileo was an "alien" coming from "foreign regions" to raid the possessions of philosophy. He had a corporate identity only in the peculiar sense that courtiers had one. As we can see from his self-representation in the negotiations with the Grand Duke for the position of "Philosopher and Mathematician" at court, Galileo was a producer of novelties.[72] Anthropologists would probably classify Galileo as a "Big Man".[73] Weber would have termed him a "charismatic personality".[74]

Therefore, two radically different socio-professional identities (associated with different social institutions) were confronting each other behind the unmomentous issue of buoyancy. This helps us understand the implications of Galileo's asking the philosophers to learn mathematics. To an Aristotelian, to learn mathematics and to accept it as a method for the *physical* explanation of the world meant to learn the language of a previously subordinate "other" now turned alien invader. Given the institutional and power dimensions entailed by this decision, Galileo was inviting them to commit hara-kiri.[75]

For quite similar reasons, the Aristotelians resisted Galileo's physical principles such as *momento*. In the *Discourse*, Galileo claimed to borrow the meaning of *momento* from mechanics.[76] But, dismissing Galileo's explicit "ostension", the Anonymous Academician criticized him for not defining it. He claimed that *momentum* was a Latin term, but that Galileo did not use it according to

[71] *Ibid.*, p. 156.

[72] *GO*, Vol. X, p. 351.

[73] M. Douglas, *Natural Symbols*, pp. 128–129.

[74] M. Weber, 'The Sociology of Charismatic Authority', *From Max Weber*, H. H. Gerth and C. Wright Mills (eds) (New York, Oxford University Press, 1946), pp. 245–252.

[75] I think that other well-publicized instances of philosophers' "stubbornness" can be related to the same dynamics of preservation of one's socio-professional identity which results in the unwillingness to learn the language of the "other". The Paduan philosopher Cremonini's refusal to look through Galileo's telescope in 1610, or to mention his discoveries in the 1613 *Disputatio de coelo* is an example of this type of behaviour. *GO*, Vol. XI, p. 165. The accusations of *petitio principii* mentioned in footnote 51 may also be examples of this type of reaction.

[76] *GO*, Vol. IV, p. 68. On the various meanings attributed by Galileo to "momento", see P. Galluzzi, *Momento: Studi Galileiani* (Roma: Edizioni dell'Ateneo & Bizzarri, 1972).

its Latin–Ptolemaic meaning. The Academician then looked it up as a vernacular term in the dictionary of the *Accademia della Crusca* (the canon of the Florentine vernacular) but, to his surprise, *momento* was not listed.[77] In short, while the Anonymous Academician knew where the meaning of *momeuto* was to be found, for Galileo indicated that he was borrowing the term from the *scienza meccanica,* he could not accept a notion coming from a discipline, such as mechanics, so much lower in status than his. Such a borrowing would have entailed a pollution of his professional self.

Therefore, contrary to Galileo's and Kuhn's claims, to believe in the *a priori* possibility of bilingualism is to assume conditions that may not be met in actual social contexts. Although the implications of learning the "other's" language are not always as drastic as those faced by the Aristotelians, nevertheless, when to learn the language of the "other" implies entertaining another socio-professional identity, then to be bilingual means, in a sense, to be "schizophrenic".

But if Galileo was being rhetorical in blaming the Aristotelians for not learning mathematics, he was right in saying that he could read Aristotle. And, I believe, Galileo was not "schizophrenic" either. This observation does not contradict what I just said. I have metaphorically associated bilingualism with schizophrenia in those cases in which adopting a language implies entertaining a different socio-professional identity. This was not the case with Galileo. Aristotelianism was the language (and maybe the identity) of his *past,* when he was a medical student at Pisa. Galileo's competence in Aristotelian philosophy and language was a useful fossil — one with no socio-professional identity attached to it.

More generally, members of the emerging (or invading) group can be bilingual if they were previously trained in the lexical structure of the old group but dropped it early in their careers — as Kuhn has noticed in the case of the members of the new paradigm. Like traders who speak different languages to the different people they visit without sharing in their cultural identity, the "invaders" can use the language of the adversary without adopting the socio-professional identity associated with it. Moreover, while members of established socio-professional groups have much to lose from becoming bilingual, bilingualism is strategically important to the "invaders" (or the traders). If they want to invade a disciplinary domain (or a hostile market) they must know or learn something about it.

In short, bilingualism does not need to produce dialogue across incommensurable lexical structures but it can help reinforce the confidence of the "invaders" by giving them a sense of mastering the enemy's point of view. Also, by sharing the language but not the identity of the Aristotelians, we see

[77] *GO*, Vol. IV, p. 158.

that Galileo may not have fully understood how and in what ways they felt threatened by his demand that they learn mathematics. His apparent inability to understand what he perceived as their "stubbornness" (and therefore unethicalness) may have reduced his willingness to communicate with them.[78] Therefore, bilingualism ended up reinforcing (rather than questioning) Galileo's own socio-professional identity.

VII. Conclusions

To conclude, I would like to indicate which aspects of this analysis I consider as specifically related to this example and which ones may have a more general currency within the debate on the phenomenon and role of incommensurability in the process of scientific change.

This brief case study refers to a socio-professional context characterized by a strong hierarchical ordering of disciplines that contributed to make the members of the higher disciplines unwilling to engage in dialogue with the subordinate "other". The study does not present a clear-cut case of scientific change resulting from the speciation *within* one discipline or socio-professional group, but rather an attack on the hierarchy *between* two related disciplines caused by the speciation of the subordinate group into a "higher" species. However, it would not be proper to say that the lexical structures of the philosophers and the mathematicians were already incommensurable before the "speciation" began, that is, before the work of Copernicus, Kepler, or Galileo. In fact, according to the existing disciplinary hierarchy, the mathematicians' lexical structures were not supposed to extend into the philosophers' world. Consequently, there was no room for incommensurability because the very possibility of overlap and comparison was ruled out in principle.

Copernican astronomy and the Archimedean theory of buoyancy allowed mathematicians like Galileo to consider themselves "philosophers" and — as a result of this emerging new socio-professional identity — to articulate the mathematical method into a fairly comprehensive view of the *physical* world. It was through this process of conceptual articulation and identity formation that the new philosophers' lexical structure branched into the Aristotelian philosophers' domain and became incommensurable with theirs. Galileo's speciating into a philosopher was not just a matter of changing his lexical structure but it involved an institutional migration away from the Aristotelian-controlled university to a more suitable ecological niche: the court. Whether Galileo speciated conceptually at the university of Padua or at the Medici court is, I think, beside the point. What matters is that he could *legitimately act* as a member of a new species only in a niche like the Medici court. It was there that

[78]Galileo may have consciously adopted these strategies, but they may also have been the tacit effect of a "selective perception" of the "other" resulting from Galileo's identity. See note 81 for related considerations.

he could *express* the incommensurability between his views and those of the philosophers.

Although this case study refers to a period in which science was not institutionalized, reward systems (and, to some extent, disciplinary hiererarchies) are still around and influential in directing scientific activities. Moreover, this analysis indicates a range of social dynamics that are crucial for understanding the (un)communicative behaviour of different groups competing for the legitimation or preservation of their explanation of the physical world. These dynamics are related to the identity one develops by recognizing him/herself as part of a group or "movement".[79] Being expressions of the response to the "other", their structure (but not their content) is not completely tied to specific historical contexts. Therefore, the relationship between preservation of one's socio-professional identity, status, and commitment to a world view, and unwillingness to learn the language of the "other" that has been analyzed here may be also applicable to more recent science.

Similarly, I believe that the validity of my critique of Kuhn's belief in the possible role of bilingualism in allowing for comparison of incommensurable lexical structures is not limited to this specific case study. Although I do not claim that it is *logically wrong* to assume the possibility of developing bilingualism, I argue that such an assumption is unwarranted because it does not consider the fundamental relation between social groups and cognitive activity. If world views and related linguistic grids can be developed only by groups who share those grids, then those groups must maintain cohesion in order to make cognitive activity possible. Unwillingness to learn the language of the "other" is instrumental in this process *if* learning that language implies loss of socio-professional identity. The scenario resulting from everybody's willingness to learn the "other's" world view would not be characterized by a perfectly ecumenical and consequently totally rational science, but rather by the absence of *different* groups, disciplines, paradigms, and — consequently — by the absence of science itself. Therefore, it is a sort of category mistake to think of non-communicative attitudes just as the unfortunate *effect* of socio-historical contingencies. Far from being an obstacle on the path of cognitive

[79]Some readers may question my various characterizations of Galileo as a member of a group, party, movement, or socio-professional species. My answer to this question is too long to be presented here for it entails a critique of the Kuhnian notion of paradigm and scientific community and introduces patronage as the social institution through which early modern socio-professional identities were shaped in the absence of permanent and well-structured scientific institutions and curricula (see my 'Galileo's System of Patronage' forthcoming in *History of Science* 27 (1990)). There I argue that commensurable socio-professional identities can emerge not as a result of the establishment of a well-structured group but rather as a result of a number of loosely connected people experiencing similar socio-disciplinary constraints in similarly structured institutions and perceiving similar strategies (conceptual and institutional) of socio-professional emancipation. For those who liked the Darwinian metaphor, what I am proposing may be commensurable to the notion of "convergent evolution".

activity, they help provide a sort of protective and containing belt that makes cognition possible.

Some qualifications about the relationship between incommensurability and the various forms of non-communicative behaviour are probably needed. While incommensurability is a specific and fairly uncommon linguistic phenomenon in science, non-communicative behaviours, rhetorical strategies of non-dialogue, and strategic uses of bilingualism are common, non science-specific phenomena related more directly to inter-group dynamics than to lexical structures. Although these two sets of phenomena are connected, I do not see a fixed cause–effect relation between them. Rather, the modes in which incommensurability and non-communicative behaviours and strategies are mutually related seem to reflect the power distribution characteristic of the scenario in which the competing parties interact. For instance, Galileo was not publicly vocal about the incommensurability between his views and those of the Aristotelians as a mathematics professor at Padua, but he became so as soon as he understood he could migrate to court.[80]

Access to bilingualism is also influenced by the power structure. For instance, the group "in power" does not need to (or cannot) learn the language of its incommensurable "invader". Similarly, the invaders' bilingualism is also the result of lack of power because without being bilingual the invaders would not have a chance to attempt and legitimize their invasion. Also — as in the case of Tycho, Kepler, and Magini — we have cases in which people with different lexical structures are able to engage in dialogue across incommensurable positions because they think they share a commensurable socio-professional identity. By contrast, we find cases in which non-communicative behaviours can also be conscious strategies adopted before there is any real linguistic incommensurability.[81]

This array of different configurations of linguistic incommensurability and non-communicative behaviour does not mean that their relationship is an arbitrary one determined only by contingent power structures. In fact, as we have seen in the case study, power structures and disciplinary hierarchies can

[80]The fact that quite probably Galileo was behind the fictitious Cecco di Ronchitti who wrote a devastating and somewhat obscene dialogue in Paduan dialect in which a landsurveyor ridicules the philosophers' interpretation of the nova of 1604 indicates that Galileo took a public dismissive stand about the philosophers' methodology *only under a pseudonym* while he was a university professor. An English translation of Cecco's dialogue is in S. Drake, *Galileo Against the Philosophers* (Los Angeles: Zeitlin & Ver Brugge, 1976), pp. 31–51.

[81]One model that could relate — although incompletely — linguistic incommensurability and non-communicative behaviours is offered by De Saussure's distinction between *langue* and *parole* (or Chomsky's competence/performance model). One could relate the lexical structure of the group (that responsible for incommensurability) to *langue*, while considering the individual's possibly rhetorical statements of incommunicability as belonging to *parole*. Sometimes, non-communicative behaviour would reflect an actual state of incommensurability (i.e. it would come from *langue*), while, in other circumstances, it would be uttered as private statements, reflecting personal perceptions or strategies rather than the group's lexical structure.

be modified by the development of new socio-professional groups which emerge by articulating their lexical structures (i.e. by "growing incommensurable") and by adopting the appropriate strategies of non communication *vis-à-vis* the surrounding "species".

For instance, in the more general case of speciation within a socio-professional group, the sub-group's initial unwillingness to talk to the rest of the group may be a rhetorical strategy. In fact, at such an early stage of the speciation process, it is quite probable that the linguistic grid of the sub-group would be still largely commensurable with that of the group. But the cohesion of the sub-group obtained also through strategies of non-communication would allow its members to develop a different socio-professional identity which would allow for, and *commit* them to the development their new world view. After a while, the new linguistic grid so developed by the sub-group would actually become linguistically incommensurable with the old one. Linguistic "sterility" between the sub-group and the rest would then intervene. The variety would have turned into a species.[82]

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[82]The function of incommensurability-oriented forms of non-communicative behaviour is not unlike the one Feyerabend attributed to "propaganda" in the early phases of the development of a new world-view, *Against Method* (London: Verso, 1974), especially pp. 145–161.