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FROM COMMON SENSIBLES TO PRIMARY PROPERTIES. RETHINKING GALILEI'S FAMOUS DISTINCTION IN *IL SAGGIATORE*

1. Introduction: from the distinction between proper and common sensibles to primary properties

Historians of science have almost ever paid attention rather to the origins of the theory of Galilei's *Il saggiatore*, according to which the *greatest book* of nature is written in a mathematical language than to its meaning and truth. Thereby many different interpretations have risen for 50 years and they are as much divergent as provided in a way or another with *facts*[1]. So it seems necessary to reconsider *what is* the new image of nature Galilei sets and *how* he shows that it is related to reality. This image is not simply based on the distinction between objective or primary properties and sensible qualities or subjective properties of physical objects, but it is the result of a new settlement of the relationship between the subject of knowledge and the object of knowledge and of a peculiar ontological commitment as well.

My proposal is to show that Galilei could have made such a new settlement, because he checked the basic distinction of Aristotle's theory of knowledge between proper and common sensibles and completely changed its meaning and value. According to the Greek philosopher, the proper sensibles are images of properties that *really* inhere to physical objects and their differences depend on the sense that feels each of them: examples of this kind are colours, sounds and flavours[2]. Common sensibles are five in all (size, magnitude, shape, movement and rest) and represent (literally speaking) the general features of proper sensibles. They are not felt specifically by one of the five

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[1] Recently, the Italian historian of Science Paolo Rossi Monti characterized even *seven Galileis*, and all of them seem to be real. In fact, he identifies seven different interpretations of the contribution of Galilei to the development of scientific thought, which draws as many images of the Pisan scientist, ranging from those of Whewell and Mach (Galileo as father of the experimental method) to those of Duhem and Randall (Galilei remained essentially an Aristotelian) and, more recently, from that of Koyré (Galileo was a Platonist, which almost never realized the experiments he described) to that of Drake (Galilei as a pure experimenter). Finally we find the paradoxical reconstruction of Feyerabend in *Against Method*: Galilei was an able orator, who defeated his opponents not by the scientific results he obtained, but because of his ability to argue. See: P. Rossi Monti, *Ci sono molti Galilei?* in: P. Rossi Monti, *Un altro presente: saggi sulla storia della filosofia*, Il Mulino, Bologna 1999.

[2] See Aristotle, *On the Soul* II, 418a11–14.

senses but, anyhow we feel anything, they all are felt at the same time[1].

Science of optics from Hellenistic period to Late Middle Ages paid much attention to common sensibles, but those who brought about its development, specially to the so–called *Perspectivi* (Alhazen, Witelo, Roger Bacon, Pecham)[2], thought that the subject of knowledge perceives proper sensibles, but he makes mistakes when he considers common sensibles. In fact, they are derived from the proper ones and are not direct data. On the contrary, according to Galilei common sensibles are a solid empirical basis in science, if they are taken as real properties of matter. In fact, they outline the field of sensitive experience that all the conscious subjects share.

But *how* could Galilei justify such a completely reversal of that basic Aristotelian distinction? There are many reasons to be taken into account, but in my opinion no one has been analyzed in a suitable way. Crombie explained this turning–point in the history of science as if it were a step Galilei was forced to take:

> *Galileo's eventual answer was the account in* Il saggiatore *(1623) of the 'primary and real properties' (shape, size, location in place and time, touching or not, number, slow and swift motion) which he found himself obliged to attribute to matter, as distinct from the secondary qualities of sensation, these produced in the 'animate and sensitive body'.*[3]

I think there were epistemological and ontological reasons instead. They persuaded Galilei to make common sensibles equal to primary properties of matter and to bind them to bodies and their mental images.

It is timely to check how Galilei's idea was born by comparing the most important passages in his works in which he took common sensibles into consideration. In so doing, I hope we can understand how he realized their transformation in primary properties in two different moments in his life as a scientist: 1) first of all, the controversy on the reliability of the observations through the telescope, described in 1610 *Sidereus Nuncius*, 2) the lengthy one with Orazio Grassi, concerning what comets are.

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[1] See Aristotle, *On the Soul* II, 418a17–19: *Common sensibles are movement, rest, number, figure, magnitude; these are not special to any one sense, but are common to all. There are at any rate certain kinds of movement which are perceptible both by touch and by sight.*

[2] Among *Perspectivi* there are many differences concerning the number of common sensibile: Alhazen lists 22 of them, Roger Bacon 20, in the Late Middle Ages the number of them was reduced to 5 or 6. See: A. I. Sabra (ed.), *The Optics of Ibn al–Haytham. Books I–III on Direct Vision*, translated with commentary and introduction, The Warburg Institute (University of London), London 1989, vol. 1, pp. 138–139, D. Lindberg (ed.), *Roger Bacon and the Origins of* Perspectiva *in the Middle Ages*, a critical edition and English translation of Bacon's *Perspectiva* with introduction and notes, Clarendon Press, Oxford 1996, p. 8. See also: K. H. Tachau, *Vision and Certitude in the Age of Ockham. Optics, Epistemology and the Foundations of Semantics (1250–1345)*, E. J. Brill, Leiden – New York – København – Köln 1988.

[3] A. C. Crombie, *The Primary Properties and Secondary Qualities in Galileo Galilei's Natural Philosophy* in: C. Maccagni (ed.), *Saggi su Galileo Galilei*, vol. 2, Barbera, Firenze 1972, p. 77.

2. The controversy on the discoveries by telescope: proper and common properties of sensible data

2. 1. The controversy with Ludovico delle Colombe

First of all, I will take into consideration Ludovico Delle Colombe's essay *Contro il moto della Terra*. In its last pages he discusses the problem if on the surface of the Moon there really are mountains and valleys, which Galilei was sure to have observed through the telescope, as he described in his *Sidereus Nuncius*[1]. Delle Colombe maintains that mountains and valleys on the lunar surface are only appearances: Galilei's *observations* are no more than sense deceptions[2]. The irregularities he found could be explained if the distinction between proper and common sensibles is taken into account, in other words if we are aware of the way we change sensations into valid observations.

As Aristotle had taught, it is easier that senses are wrong about common sensibles than about proper ones, because they are right for bringing the latter from which the common sensibles come[3]. Among common sensibles, Delle Colombe lists shape, location, movement, arrangement of parts. He deduces that eventually mountains and valleys on lunar surface are included in this set. Therefore it is likely that they are the results of a whole sense deception. In his opinion, the presence of these irregularities could be better explained, *physically speaking*, by postulating that the matter of the Moon is here thick and there rare:

> *Why are we looking for instances among the lower things, since it is very clear in Heaven itself? Who cannot see that heavenly matter, in those parts where it is rarer and without stars, is so transparent that our sight, in order to see the fixed stars, passes through the thickness of seven spheres, as if there were not anything? Then, is there anyone who doubts that our eyes cannot see the parts of the lunar body, that neither are thick and reflect the Sun beams nor put an end to our sight, and that therefore the Moon does not seem round and smooth?*[4]

Galilei remarks that Delle Colombe argues senses are deceived on common sensibles, but he does not debate the question how the illusion results. He suggests, then, that what appears to be can be explained by postulating either rarity and density or mountains and valleys in lunar body, but he chooses the second hypothesis without giving any other reasons unless the presumed per-

[1] Ludovico delle Colombe, *Contro il moto della Terra (con postille di Galileo)* in: Galileo Galilei, *Opere*, ristampa dell'ed. nazionale diretta da A. Favaro, Barbera, Firenze 1930, vol. III/1, pp. 251–290.

[2] Delle Colombe, *Contro il moto*, pp. 286–288.

[3] Delle Colombe, *Contro il moto*, p. 286. See also Aristotle, *On the Soul* III, 428b18–25.

[4] Delle Colombe, *Contro il moto*, p. 287: *Ma a che fine andiamo noi cercando esempi nelle cose inferiori, se pure troppo è chiaro nello stesso Cielo? Chi non vede, che la materia celeste è tanto trasparente in quelle parti dove essa è rara e senza stelle, che per la grossezza di sette Cieli penetra la nostra vista, come se non vi fossero, a veder le stelle del Firmamento? Dubiterassi adunque, che quelle parti del corpo lunare, che dense non sono e non riflettono il raggio solare, né terminan la vista altrui, non si possono dall'occhi nostri vedere, e che perciò rotonda e liscia la Luna non appaia?*.

fection of Heavens[1]. Galilei skims over the distinction between physical and mathematical reasons. His attitude will been explained in what follows, but since now we should bear in mind that this distinction justifies, in a peculiar way of course, Delle Colombe's choice.

2. 2. La Galla and the sense deceptions

In 1612 Giulio Cesare La Galla, head professor in Ginnasio Romano, gave a lecture at the University of Rome, that he introduced as a *Physica disputatio*. It was the opportunity to support the use of telescope, but specifically with reference to the irregularities on the lunar surface his opinion was the same as Delle Colombe's, whose motives he deepened[2].

Once again he maintains that the question *What kind of irregularities are there on the surface of the Moon?* must be taken into consideration *from a physical, rather than a mathematical point of view*. In fact, Aristotle had taught that mathematics concerns properties that really inhere to physical beings, but it regards them only as abstracted from those beings. Then, mathematics is not useful, if we would know how things happens *naturally*[3]. That is the crucial point in the discussion on sense deception, during which Galilei brings about a complete turning concerning the traditional scientific methodology. In his personal remarks to La Galla he replies that it is as much naïve to maintain that geometry and arithmetic cannot be found in things as if they were *physical* properties, as to say that the training and coordinating rules do not suit to an army, whenever we regard soldiers as physical bodies. In short, Galilei's opinion is that mathematical properties are the same, either they are regarded as abstract or inhering to bodies[4].

According to La Galla, the distinction between proper and common sensibles seems basic to explain how it happens to be wrong when the mathematical properties of bodies are taken into account. Common sensibles are the main source of illusions, because they are farther from each sense than the proper ones and also because they are not felt by one sense, but by all of them. There would be a demonstration of a such an utterance in the case of a stick that seems to be broken, if it is plunged in water: sight makes us wrong, but touch testifies how things really are[5]. Galilei's reply to these considerations can be summarized as follows: mistakes are not due to the sense (I see the stick is broken). It is the statement we produce from sensitive

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[1] Delle Colombe, *Contro il moto*, p. 288, n. 42.

[2] Giulio Cesare La Galla, *De phaenomenis in orbe lunae nunc iterum suscitatis (con postille di Galileo)* in: Galilei, *Opere* III/1, pp. 309–399.

[3] La Galla, *De phaenomenis*, p. 323.

[4] La Galla, *De phaenomenis*, pp. 323–324, n. 1: *Quaeritur, nunquid considerationes mathematicae circa Caelum sitne physicae an mathematicae: si enim sunt mathematicae, tempora eclipsium, coniunctionum etc., cum sensibilibus et realibus coniunctionibus non congruent. Non minus est ridiculum dicere geometrica non respondere in materialibus, ac si quis dixerit arithmeticas passiones in sensibilibus corporibus non respondere; et, v.g., regulae instruendi et coordinandi exercitum non respondere, dum corporeos milites accipimus.*

[5] La Galla, *De phaenomenis*, 324.

data that can be wrong (*The stick is broken*)[1]. Finally, La Galla remarks that by the laws of *Perspectiva* we become aware of the illusions due to common sensibles; about the irregularities on the lunar surface, he repeats Delle Colombe's motive. Even if they can be perceived *ex parte organii et telescopii*, the conclusion that they really exist must not be drawn *ratione obiecti*. In other words, it can be supposed they exist from a mathematical, but not from a physical point of view:

> *On the other hand, I say that the circumstances of deception cannot be found in the organs and in the little lens of telescope, as someone maintained* [...], *but the deception is due to the object, because it cannot be that these phainomena appear on the surface of the Moon, and they are not due to such a very long distance, but to brightness and dullness, whose varied mixture is to be supposed.*[2]

We can divide Galilei's replay into two parts. First of all, in a short personal remark he stresses that, if *Perspectiva* gives us information about perceptive errors, it teaches us how to correct sense deceptions[3]. Then, in the last remarks, he deepens the analysis of that crucial motive and, if we forced just a little his words, we would draw the following conclusions: 1) if it is true that sense can be wrong about common sensibles, we cannot deny that it can be wrong about proper sensibles, too, and in the same ways, but 2) the correction of any deception concerns only the common sensibles[4]:

> *You mean to say that mathematicians are guilty of ignorance, because they did not realize that senses are wrong about common sensibles, as if it were a hidden and very deep mystery, and secret, of Philosophy, to know if they are wrong or not. But who has gathered more observations and analyzed with more accuracy sight deceptions, than mathematicians themselves?*[5]

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[1] See La Galla, *De phaenomenis*, nota 3, 324: «Hanc deceptionem non credo esse ipsius sensus, sed rationis iudicium ferentis; nam et simitas nasi et crispitudo recte percipiuntur a visu».

[2] La Galla, *De phaenomenis*, p. 325: *Dico autem occasionem deceptionis, non ex parte organi et telescopii perspicilli, ut aliqui dixerunt* [...] *sed ratione obiecti; quod aliter videri non possit, non ex distantia quam longissima, sed ratione lumini set opaci, ex quorum varia mixtione probabile est, haec phoenomena in orbe Lunae, de quibus disputationem instituimus, apparere.*

[3] See La Galla, *De phaenomenis*, p. 325, nn. 5–6.

[4] After La Galla's *Disputatio*, a long list of Galilei's loose remarks have been published in the complete edition of his works. They lay in the starting and final fly–leaves of the *Disputatio* copy he owned. Galilei devoted many remarks – if the first incomplete two are not taken into account, precisely the half – to sense deceptions and above all to those due to common sensibles. La Galla, *De phaenomenis*, pp. 393–399.

[5] La Galla, *De phaenomenis*, p. 397: *Volete incolpare i matematici d'ignoranza, per non si esser accorti che il senso ne i sensibili comuni s'inganna; quasi che il sapere s'ei s'inganna o no, sia un recondito e profondissimo misterio e segreto della filosofia. Ma chi ha fatto maggiori e più esatte osservazioni e speculazioni intorno a gl'inganni della vista, che i medesimi matematici?*

There is not any secret that lies in sense deceptions. The most important questions concerning such issue is: *Can sense deceptions be corrected and changed into reliable observations?*

3. The conversion of common sensibles into primary and real properties: a reappraisal of the outline of atomism in *Il saggiatore*

Now I will take into account the way Galilei converted common sensibles into primary properties of any material substance on the occasion of his controversy against Orazio Grassi on comets and their origins. In *Il saggiatore* the distinction between objective (real) properties and sensible qualities is handy in order to explain the meaning of the following statement: *Motion causes heath.* Galilei promised to clarify it to Lincei academic Virginio Cesarini, to whom the work was dedicated. That statement summarizes Galilei's opinion concerning what comets are and what are their visible effects[1]. He lists the so–called *primary properties* of matter in the paragraph where he claims that no physical being can be imagined without shape, size, location, time, motion or rest, arrangement of parts, unity or multiplicity (number)[2]. Therefore Galilei regards as sound a strong epistemic argument: the concept *body* cannot be distinguished from its measurable properties and if what we are thinking of has any correspondance in any way to what really exists, then the meaning of the concept *body* should imply such a correspondance. Any other property we ascribe to material substances, for example heat or coldness, hardness and colours, lies in the subject who feels. If the subject were removed, then nothing would be left but pure names[3].

Galilei's argument is entirely different from Aristotle's opinion on this subject. It was just on the ground of this divergent opinion concerning the topic *physical properties* that the Italian scientist can reverse common sensibles into primary properties and, in so doing, reverse a traditional strong idea, too. According to the Greek philosopher, material substances have *really* sensible properties, the proper ones and the common properties. They are transferred to the conscious subject who feels. Sensations are effects of action of sensible forms, that originally lies in what acts and they cause sensations by their action on senses. They bring them from potency to act and the senses have finally a new form[4]. On the contrary, according to Galilei only the latter ones are *really* properties of material substances, while the proper sensibles lie in the subject. The five senses *cause* basic sensations, which are not transferred in any *physical* way from what is felt to the subject who feels. In *Il saggiatore* a sketched theory about how sensations happen follows the account of primary properties: sensations should be effects of particles

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[1] Galileo Galilei, *Il Saggiatore* in: Galilei, *Opere* VI, pp. 197–372. So finally Galilei could write to Cesarini (p. 351): *Pare a me che non fusse se non con gran ragion detto, il moto esser causa del movimento.*

[2] Galilei, *Il Saggiatore*, pp. 347–348.

[3] Galilei, *Saggiatore*, p. 348: *Per lo che io vo pensando che questi sapori, odori, colori etc., per la parte del soggetto nel qual ci par che riseggano, non sieno altro che puri nomi, ma tengano lor residenza nel corpo sensitivo, sì che rimosso l'animal, sieno levate e annichilate tutte queste qualità.*

[4] See Aristotle, *On the Soul* II, 422b17–424b21 & III, 426b 8–427a 1.

(atoms), by which the arrangement of parts and the different shapes of bodies are made up. The *affezione del calore* (sensation of heat) is caused by the passing by of particles or the *toccamento de' minimi ignei per la nostra sostanza* (touch of elementary particles of heath through our body)[1]. Therefore these particles could definitely explain the meaning of the statement: *Motion causes heath*. In other words, sensations are felt *on the occasion* of motion of peculiar particles.

Orazio Grassi replied to Galilei's critics in his 1626 *Ratio ponderum librae et simbellae*, published under the well–known pseudonym *Lotario Sarsi*. It was his answer to *Il saggiatore* and he devoted special attention to the distinction between primary properties and sensible qualities. Grassi brings up also the matter if such a kind of distinction had dangerous outcomes concerning the relationship between science and Christian faith[2]. In fact, if Galilei was right, that is if tastes, colours and so on were only pure names as the conscious subject were removed, some properties of Host after consecration, just its taste and colours, would be only *flatus vocis*[3]. Finally, Grassi refers to the example of tickle, the same one Galilei has quoted in order to maintain that what we feel is movement of material parts of a body[4]. Grassi's aim is to show that Aristotle's opinion stands still valid. Even if motion of elementary particles caused proper sensibles to exist, it should not be right to argue that sensations lie only in the conscious subject. In fact, motion is *ex parte obiecti* and at the same time *ex parte subiecti*, in other words in what acts and in what (or who) undergoes the action. Therefore, in some way sensible qualities are really transferred[5].

4. What does reversing Aristotle's argument import? From the *common–sense* experimental method to the modern one

4. 1. Mathematics allows to correct sense deceptions

We could understand the reasons that persuaded Galilei to firmly believe, first, that matter is really provided with primary properties and then, that no one physical being can be imagined without them, if we took seriously into consideration how he emphasized the role of mathematics in making possible to correct sense deceptions.

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[1] Galilei, *Il Saggiatore*, pp. 348–349.

[2] In this work Grassi submitted to the *arbitrio Philosophorum* what he had argued in his 1619 *Libra* and in Galilei's *Saggiatore* (*Simbella*), both quoted in the title. See: Galilei, *Opere* VI, pp. 373–500.

[3] Sarsi, *Ratio ponderum et simbellae* in: Galilei, *Opere* VI, pp. 486–487. Perhaps Grassi had in mind the 11th–century controversy on Host consecration.

[4] Galilei, *Saggiatore*, p. 348: *Venendo toccato, v.g., sotto le piante de' piedi, sopra le ginocchia o sotto l'ascelle, sente, oltre al comun toccamento, un'altra affezzione, alla quale noi abbiamo imposto un nome particolare, chiamandola 'solletico': la quale affezzione è tutta nostra, e non punto della mano; e parmi che gravemente errerebbe chi volesse dire, la mano, oltre al moto ed al toccamento, avere in sé un'altra facoltà diversa da queste, cioè il solleticare, sì che il solletico fusse un accidente che risedesse in lei.*

[5] Sarsi, *Ratio ponderum et simbellae*, p. 486. It is to be remarked that Grassi brings Galilei's theory back to the *schola Democriti*. To be charged with atomism was very dangerous in the Counter–Reformation Eve and that was the real accusation Galilei was charged with in 1633, according to Redondi. See E. Redondi, *Galileo eretico*, Einaudi, Torino 1983 [revised ed. 2004].

Shall we have a look at the example of the stick plunged in water. Error does not lie in sensation (we *really* see a broken stick), but rather in the statement concerning the properties of the stick we express (*The stick is broken*). It would be even wrong to talk about *error* with reference to sensations, but if the aim is to understand what kind of error lies in the statement above quoted, then it might be used such an improper way of speaking. First of all, there is no sound reason for the stick to be broken, if it was whole outside water. Then, the laws of optics (a mathematical science) according to Aristotelian philosophy[1] foretell that light beams undergo refraction, whenever they pass from a rarer *medium* (air) to a thicker one (water) and vice versa, and that is why the stick *appears* broken even if it is *in reality* whole. Finally, optics makes possible to foretell even the degree of refraction, in other words the measure of *breaking* the sight perceives, since it is known the density of *media* such as air and water. Therefore, sight deceptions can be marked in any case of that kind and so it can be confirmed that the statement *the stick is broken* is false.

Reality Galilei has in mind is what I can call *the structured set* not of elementary experiences – in fact, they are subjective and sometimes chance – but rather of the corrected ones, that is the confirmed by measurement experiences. Galilei's argument can be divided into three parts: 1) when what causes sense deceptions is known, it can be explained how they happen and information that comes from a naïve observation can be corrected, 2) *only* when it is possible to correct sense deceptions, it can be achieved a valid knowledge of experience data, since sensations are originally subjective, 3) *only* common experience data can be corrected, that is the ones any perceived object shares in common with the others and any conscious subject perceives, and even subjective sensations, if they are reported to common data (location, shape, motion, order of parts, size, and so on) as their complex signs.

To sum up, *nature* Galilei has in mind is never a set of immediate data, but rather the result of a progressive adaptation of mind to reality. Here *adaptation* does not mean *perfect correspondance*, but *improvable correspondance*. And science is the result of such an adaptation. In fact, it is not achieved starting from absolute and doubtless data as proper sensibles Aristotle thought of, but choosing experience data that can be put under control. Observation of nature, whatever it means, is a feeble and changeable starting point, as Galilei remarks, and science derives often from forced sensations. The main example he quotes is the Earth motion, that is not an immediate *datum*. Copernic has to be praised, because he forced common–sense experience to achieve a real image of Heavens:

> *We have just understood, that the motives against Earth daily motion you have already analyzed seem to be the most valid. Tolemians and Aristotelians and their followers regarded them as absolutely definitive. This is a very strong argument supporting*

[1] See Aristotle, *Physics* II, 194a7–11.

> *its effectiveness. But the motives that clearly stand against the annual motion are so even more repulsive, that (I tell it one more time) I cannot help me to stop admiring the way Aristarchus and Copernicus' minds could have so forced the sense, that against it the mind itself became the master of their belief.*[1]

Therefore, science is the result of the interaction between mind and Nature; without such an interaction anyone would not become convinced of Earth motion.

4. 2. The grounds of the new mathematical physics: epistemic arguments and ontological commitment

Galilei did not explain in details the new image of nature he supported. In *Il saggiatore* an outline of atomism appears, as it is well–known, but what we can read are few considerations and we may not draw from them definitive conclusions. It is sure that, according to Galilei, scientific thinking does not move forward merely through *trials and errors*, as Popper thought, but through a progressive adaptation of mind to experienced reality: when nature answers in an understandable way to our questions and when it turns out that any answer looks like any other in cases of the same kind, to speak a figurative language, then the cognitive trail finds a still point.

Now it is needed to pay attention not only to the corrections mathematics allows[2], but also to the fact that the Aristotelian distinction between physical arguments and mathematical ones becomes insignificant. According to Delle Colombe and La Galla, arguing from a physical point of view and arguing from a mathematical one do not lie at the same epistemic level. Since the Moon cannot have mountains and valleys on its surface from a physical point of view, then what can be observed through the telescope and seems to be mountains and valleys at first sight must be explained in a different way. According to Galilei this distinction is completely useless. In fact it deserves only few remarks. However, he is able to support the effectiveness of the observations through the telescope both working on mathematics as a corrective tool and undertaking an ontological commitment and a strong epistemic argument.

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[1] Galileo Galilei, *Dialogo sopra i due massimi sistemi del mondo* in: Galilei, *Opere* VII, p. 355: *Che le ragioni contro alla vertigine diurna della Terra, già esaminate da voi, abbiano grandissima apparenza, già l'abbiamo veduto, e l'averle ricevute per concludentissime i Tolemaici, gli Aristotelici e tutti i lor seguaci, è ben grandissimo argomento della loro efficacia; ma quelle esperienze che apertamente contrariano al movimento annuo, son ben di tanto più apparente ripugnanza, che (lo torno a dire) non posso trovar termine all'ammirazione mia, come abbia possuto in Aristarco e nel Copernico far la ragion tanta violenza al senso, che contro a questo ella si sia fatta padrona della loro credulità.*

[2] Many historians of science stressed, e.g. A. C. Crombie, *Augustine to Galileo*, Cambridge (MA), Harvard University Press 1953, p. 295, that Galilei often referred to an Archimedean pattern of scientific research. That is right, but I do not agree with them, as they argue that it means Galilei had in mind a mathematical plot he firmly supposed to find identical in reality. It would be needed a deep comparison between Galilei's idea of the relation between physics and mathematics and Archimedes' distinction between mechanical and geometrical demonstrations, but it is not now specifically necessary.

Nothing made up of matter could be imagined as if it lacked primary properties. This is an epistemic and ontological argument at the same time: it neither exists nor can be imagined an x (material substance) which has not peculiar properties, that is to say, that the statement 'x is in a place', if x is made up of matter, has the same meaning as 'x is x'. Aristotle thought that mathematical properties existed in reality as properties of material substances, but just because *so they are* and mathematics take them into account *only as abstracted* from matter, therefore subject–matters of physics and mathematics are completely different[1]. Mathematics is about *border* characteristics of material substances. Galilei reversed the Aristotelian image of nature, just because he regarded mathematics as the key by which physical events can be explained: he took sensible qualities away from the field of physics and within the range of possibilities of human understanding he put only primary properties. Therefore, physics is about common universal properties of bodies and of their relationships and it fixes proportions, order of magnitudes and so on. The conclusion we can draw is that there cannot be a physical argument that is not at the same time a mathematical one. Originally the conscious subject deals with rough experience data. Mathematics allows to move forward to science by progressively adjusting the relationship between mind and nature.

5. Conclusion: the rule *tolerate approximation*

Galilei escaped the sceptic argument, according to which sensible experience is always subjective and cannot therefore lead to science: in fact, he singled out some *anthropological* constants in sensations, as the common sensibles *converted into* primary properties should be called. From this starting point, he outlined a map of nature to read which mathematics is needed. His point of view is not Platonic: Nature *is written* in a mathematical language, but it *is not made of* mathematical elementary beings. The motto *tolerate approximation* can summarize his whole theory: he did not state the idea that there is a mathematical reality under and beyond appearances as a sort of transcendental reality, but it is easy to understand that Galilei firmly believed that any physical event leans to conform to a mathematical pattern. Sure, the adaptation is perfect only in mind, but in reality there are many imperfect examples at different levels of imperfection of the pattern. It is necessary to tolerate approximation, if the aim is to understand how nature works.

The mental attitude of Galilei towards Nature is, therefore, in accordance with the current meaning of *science*. Thanks to him, *science* began to mean not only demonstrated knowledge from universal and necessary premises, according to Aristotle's definition, but also the kind of knowledge that *can be* corrected and, consequently, is cumulative. Rossi Monti's recall to consider the past in history of science as *another present* should be accepted[2]: the

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[1] Aristotle, *Physics* II, 193b31–35: *Now the mathematician, though he too treats of these things, nevertheless does not treat of them as the limits of a natural body; nor does he considers the attributes indicated as the attributes of such bodies. That is why he separates them; for in thought they are separable from motion, and it makes no difference nor does any falsity result, if they are separated.* See also Aristotle, *Metaphysics* VI, 1025b19–32.

[2] See footnote n. 1, p. 192.

world Galilei saw, described and explained is not *perfectly* comparable to the one *we* see, describe and explain. There is, nevertheless, a serious risk, if you accept to read history of science as a set of so many stories, none of which is *properly* true: considering Galilei's laws of motion as mere historical products, which mean something only within the context in which they were drafted, hides the real contribution of the Pisan scientist to the development of science.

I object strongly to this argument: Galilei did not know how to justify *the fact* that the Earth turns around the Sun, but he traced the road to its demonstration. Today, the motions of the Earth are *proven facts*, *not historical products*. If Rossi Monti was right, Galilei's theory of motion would have the same truth–value as Aristotle's one, but today *no one can deny* that Aristotle's theory is completely wrong, while Galilei's one is a special case of an overall theory of the motion, still under arrangement, that does not eliminate, but states and corrects it.