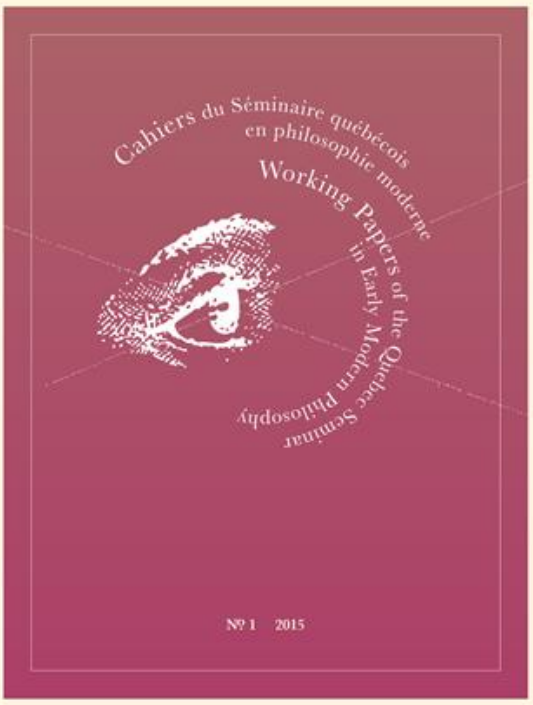



# Filip Buyse


## The Distinction between Primary Properties and Secondary Qualities in Galileo Galilei's Natural Philosophy


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**Abstract**
In *Il Saggiatore* (1623), Galileo makes a strict distinction between primary and secondary qualities. Although this distinction continues to be debated in philosophical literature up to this very day, Galileo's views on the matter, as well as their impact on his contemporaries and other philosophers, have yet to be sufficiently documented. The present paper helps to clear up Galileo's ideas on the subject by avoiding some of the misunderstandings that have arisen due to faulty translations of his work. In particular, it shows how Galileo's distinction directly implicates a novel understanding of physical bodies, which played an important part in his later condemnation by the Catholic Church. At the same time, the paper also argues that Galileo's distinction can already be found in the text and illustrations of earlier, popular Copernican writings.

**Résumé**
Dans *Il Saggiatore* (1623), Galilée fait une distinction claire entre qualités primaires et secondaires. Bien que cette distinction continue à faire l'objet de débats, la doctrine de Galilée et son impact sur d'autres philosophes ne sont pas suffisamment documentés dans la littérature secondaire. Cet article contribue à éclairer les idées de Galilée en évitant certains des malentendus qui ont surgi en raison de traductions incorrectes du texte original. En particulier, il montre comment la distinction implique une nouvelle définition des corps qui a joué un rôle dans la condamnation de l'auteur du Dialogo. Du même souffle, l'article fait valoir que la distinction se trouvait déjà dans le texte et les illustrations de précédents écrits coperniciens.

# The Distinction between Primary Properties and Secondary Qualities in Galileo Galilei's Natural Philosophy[1]

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> This form of the primary–secondary distinction in Galileo is worth a moment's pause, for its effects in modern thought have been of incalculable importance. It is a fundamental step toward that banishing of man from the great world of nature and his treatment as an effect of what happens in the latter, which has been a pretty constant feature of the philosophy of modern science, a procedure enormously simplifying the field of science, but bringing in its train the big metaphysical and especially epistemological problems of modern philosophy (Burtt, 2003: 89).

## *Introduction*

The distinction between the primary properties and secondary qualities of bodies is important to modern philosophy. Indeed, according to David Hume (1711-1776), it is the fundamental principle of that new philosophy:

> The fundamental principle of that philosophy is the opinion concerning colours, sounds, tastes, smells, heat and cold; which it asserts to be nothing but impressions in the mind, deriv'd from the operation of external objects, and

[1] This paper is based on two talks on the distinction between primary properties and secondary qualities in Galileo. The first was given on September 28, 2012, during the Quebec Seminar in Early Modern Philosophy, and the second on April 8, 2013, at the University of Oklahoma's History of Science Collections of the Bizzell Libraries.

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> without any resemblance to the qualities of the objects. Upon examination, I find only one of the reasons commonly produc'd for this opinion to be satisfactory, *viz.* that deriv'd from the variations of those impressions, even while the external object, to all appearance, continues the same. [...]
>
> This principle being once admitted, all the other doctrines of that philosophy seem to follow by an easy consequence. For upon the removal of sounds, colours, heat, cold, and other sensible qualities, from the rank of continu'd independent existences we are reduc'd merely to what are called primary qualities as the only real ones, of which we have any adequate notion (Hume, 1992: 226-227).

We find this distinction in the philosophy of important and influential early modern philosophers such as Locke (1632-1704), Boyle (1627-1691), Hobbes (1588-1679) and Descartes (1596-1650), although these philosophers use indeed different terminologies.

The primary-secondary distinction is regularly discussed in the secondary literature. Recently, Lawrence Nolan edited a collection entitled *Primary and Secondary Qualities. The Historical and Ongoing Debate* (2011); this volume contains essays on the distinction in Descartes, Boyle, Hume, Gassendi (1592-1655) and Berkeley (1685-1753), with special attention being paid to Locke. Amazingly, however, there is no essay on Galileo, and to my knowledge no such work has appeared since Alistair Cameron Crombie's 1967 article on the topic (see Crombie, 1967), even though scholars agree that Galileo was the first post-classical philosopher to publish this distinction, in his *Saggiatore*[2] of 1623. What is the reason for this neglect?

The distinction of primary-secondary qualities in Galileo's work has rarely been discussed in philosophical literature because it is believed that Galileo introduced this distinction in a small, rather isolated fragment of some four pages in a book that he wrote in Italian, not Latin, and which was thus not well known northern of the Alps. As Peter R. Anstey puts it, the prevailing opinion is that "Galileo foreshadowed the distinction in *The Assayer* [i. e. *Il Saggiatore*]", yet "there is no evidence that this brief discussion there had any impact on Boyle or his contemporaries" (Anstey, 2000: 24-25). Most scholars also argue that Galileo's distinction goes back to ancient atomism, and moreover, that other early modern philosophers learned of the distinction from their reading of the atomists, and not from Galileo.

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[2] The only complete English translation of *Il Saggiatore*, entitled *The Assayer*, is from Stillman Drake. See Drake and O'Malley, 1960: 151-336.

The aim of this paper is threefold. Firstly, I would like to show that Galileo's distinction between primary properties and secondary qualities amounts to the introduction of a new definition of a body. Secondly, I will indicate and elucidate several problems with the English translation of the crucial passage of *Il Saggiatore*, which led to a misinterpretation of Galileo's original text. And thirdly, I would like to suggest an origin of the distinction other than ancient atomism, which is traditionally put forward as the origin of Galileo's distinction. I will argue, rather, that the distinction is already present in Galileo's Copernican writings. This approach not only sheds new light on the distinction, but also implies that it is much more likely that certain early modern philosophers learned to know of the distinction from Galileo's astronomical work, which was well-known and read throughout Europe.

## *The distinction between primary properties and secondary qualities*

Galileo wrote *The Assayer* in 1623. This book presented a polemic against the *Treatise on the Comets of 1618* by Orazio Grassi (1583-1654), a Jesuit mathematician at the Collegio Romano. *The Assayer* received immense popular acclaim (see Redondi, 1983) directly following its publication in October 1623, and was composed in Italian so that any literate Italian could engage it. It is noteworthy that even Galileo's supporter and friend, Cardinal Maffeo Barberini (1568-1644), enjoyed the book enormously. Barberini became Pope Urbanus VIII in the same year, and would later play an important role in Galileo's condemnation. As we will see below, Galileo's doctrine of qualities may have played a role in his condemnation.

In this book, which Stillman Drake has called "the greatest polemic ever written in physical science" (Drake, "Introduction: Fourth Part", in Galilei, 1957: 227), Galileo includes his famous passage on the distinction between primary properties and secondary qualities[3], which Drake translates as follows:

[3] "Per tanto io dico che ben sento tirarmi dalla necessità, subito che concepisco una materia o sostanza corporea, a concepire insieme ch'ella è terminata e figurata di questa o di quella figura, ch'ella in relazione ad altre è grande o piccola, ch'ella è in questo o quel luogo, in questo o quel tempo, ch'ella si muove o sta ferma, ch'ella tocca o non tocca un altro corpo, ch'ella è una, poche o molte, né per veruna imaginazione posso separarla da queste condizioni; ma ch'ella debba essere bianca o rossa, amara o dolce, sonora o muta, di grato o ingrato odore, non sento farmi forza alla mente di doverla

> Now I say that whenever I conceive any material or corporeal substance, I immediately feel the need to think of it as bounded, and as having this or that shape; as being large or small in relation to other things, and in some specific place at any given time; as being in motion or at rest; as touching or not touching some other body; and as being one in number, or few, or many. From these conditions I cannot separate such a substance by any stretch of my imagination. But that it must be white or red, bitter or sweet, noisy or silent, and of sweet or foul odor, my mind does not feel compelled to bring in as a necessary accompaniment. Without the senses as our guides, reason or imagination unaided would probably never arrive at qualities like these. Hence I think that tastes, odors, colors, and so on are no more than mere names so far as the object in which we place them is concerned, and that they reside only in consciousness. Hence if the living creature were removed, all these qualities would be wiped away and annihilated. But since we have imposed upon them special names, distinct from those of the other and real qualities mentioned previously, we wish to believe that they really exist as actually different from those (Galilei, 1957: 274).

In this passage from his polemical book on the nature of comets, Galileo makes a real distinction ("veramente e realmente da quelli diverse") between two kinds of affections: between what he calls the primary accidents ("primi e reali accidenti"), and qualities which he mostly refers to as "affections" ("diverse affezzioni secondo"), or rather exceptionally (see Galilei, 1890-1909: VI, 348, lines 8 and 34), as "qualities" ("qualità"). It is interesting to note that it was not Locke, but Galileo's master, Robert Boyle – the philosopher of qualities *par excellence* –, who introduced a similar terminology into English. In this paper I will call the former "properties" and the latter "qualities". The difference between these two types, for Galileo, is that primary properties belong necessarily to the body in itself ("conditizioni necessariamente accompagnata") and exist, as a consequence, independently of the observer. In short, they are mind-independent properties. Secondary affections, on the contrary, only exist – according to the passage above – in the mind of an observer. Thus, they are mind-dependent qualities.

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apprendere da cotali condizioni necessariamente accompagnata: anzi, se i sensi non ci fussero scorta, forse il discorso o l'immaginazione per se stessa non v'arriverebbe già mai. Per lo che vo io pensando che questi sapori, odori, colori, etc., per la parte del suggetto nel quale ci par che riseggano, non sieno altro che puri nomi, ma tengano solamente lor residenza nel corpo sensitivo, sì che rimosso l'animale, sieno levate ed annichilate tutte queste qualità; tuttavolta però che noi, sì come gli abbiamo imposti nomi particolari e differenti da quelli de gli altri primi e reali accidenti, volessimo credere ch'esse ancora fussero veramente e realmente da quelli diverse" (Galilei, 2005: 284-285). See also Galilei, 1890-1909: VI, 347-348.

Interestingly, in this passage, Galileo in fact introduces a new definition of a body. A body in itself is a piece of matter with only primary properties. About twenty years later, Descartes would write in his *Principia* (1644) that a body is essentially an extended thing, a *res extensa*. So, a body is for the French philosopher a way or a mode of being extended. For Galileo, a body is not limited to this one unique property, but also includes several primary properties, such as size, motion, and shape. A body is thus for Galileo, in 1623, a mode or a way of being a whole cluster of primary properties.[4]

This new doctrine of properties-qualities is one of the elements of Galileo's natural philosophy that make our common-sense pictures of objects in particular, and nature as a whole, illusory. Galileo argued that – contrary to our intuition – the sun does not move around the earth. He also argued in his new theory of motion, which he developed in the second part of his *Dialogo* (1632), that we don't need a force to maintain the motion of a heavy body in a horizontal plane. On the contrary, we need an external force to stop such motion. And, importantly for this discussion, bodies in particular and corporeal substance in general do not have any sensible qualities such as odors, sounds or colors. On the contrary, our imagination ("imaginazione") simply attributes these qualities to external bodies, so that they can be stripped off again by means of our imagination (see Galilei, 1890-1909: VI, 348). Primary properties, by way of contrast, cannot be stripped off. For example, a ball would not be the same body if we stripped off its spherical form. Galileo would argue that it can be geometrically demonstrated with certainty that the ball is spherical and not triangular or cubic.

As a consequence of Galileo's properties-qualities distinction, then, the sky is not blue and roses are not fragrant. I just experience them to be so, or they appear to me – affect me – as being like that. The real, objective world is therefore the world of the primary properties, while the realm of subjective secondary qualities is the domain of animals and human beings: "I think that if one takes away ears, tongues, and noses, there indeed remain the shapes, numbers, and motions, but not the odors, tastes, or sounds; outside the living animal these are nothing but names" (Galilei, 2008: 187).

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[4] On the primary-secondary distinction in Descartes and Galileo, see Shea, 1991: 178-179.

## *A new definition of the body*

Galileo's definition of a body in his *Saggiatore* is a new definition of a body, because it introduces several new elements, relative to the most influential interpretations of Peripatetic philosophy that had long dominated European views on corporeal substance. Firstly, a corporeal substance had traditionally been conceived as a compound of matter and form, with form being responsible for all the qualities of a particular substance. In his new definition, however, Galileo does not mention "form". Instead, he insists that the primary properties really belong to any piece of matter ("una materia o sostanza corporea") and are really different from matter's secondary qualities ("un vero accidente affezzione e qualità che realmente risegga nella material").

Secondly, Galileo's doctrine of qualities comes down to a reversal of the epistemological and ontological priority of two received lists of qualities. In his critique of the atomistic doctrine of qualities in *Sense and Sensibilia*, Aristotle made a distinction between common sensibles and proper sensibles (see Aristotle, 1984: 693-706, §436$^{b}$, 437$^{a}$, 442$^{b}$, and 445$^{b}$). Proper sensibles were prior to common sensibles, for "the Philosopher", because these properties were understood to be sensed by one exclusive sense. For example, I can only sense colours with my eyes and can only sense noise with my ears. Common sensibles, to the contrary, are sensed by several senses. For example, I can – in principle – see *and* touch the shape of a body. For Aristotle, as a consequence, the perception of these common sensibles is confused. In Galileo's doctrine, suddenly, the Peripatetic notion of "common sensibles" is substituted for by the real properties of bodies, that is, by properties belonging to a physical body in-itself, or independently of ourselves. At the same time, the Peripatetic notion of "proper sensibles" is now understood to be relative to each of the senses in question; they are, in that sense, relative qualities. Galileo explains in his marginal comments to his copy of La Galla's book, *De phaenomenis in orbe lunae novi telescopii usu nunc iterum suscitatis* (1612), that man was never deceived over common sensibles ("communia sensibilia"), as La Galla (1576-1624) had argued, but only over proper sensibles ("propria sensibilia") (see Galileo's annotations to La Galla's *De phaenomenis* in Galilei, 1890-1909: III, 323-384). Galileo thus reduced the Aristotelians' manifest qualities to being secondary qualities. The result is a shift from a qualitative, Aristotelian natural philosophy in terms of contraries, towards a quantitative natural philosophy in the form of a linear scale.

*A Galilean definition of the body*

Galileo's definition of body is not only new, it is also a typical Galilean definition, since it implies several elements which are obviously connected to discoveries and/or inventions that he himself was responsible for.

In the first place, when Galileo mentions "corporeal substance" ("una materia o sostanza corporea") in the definition above quoted, he is referring to the unique substance which composes all the bodies in the universe. With the observations made with Galileo's improved version of the Dutch telescope at the end of 1609 and the beginning of 1610, which he described in his *Sidereus Nuncius* (1610), the heterogeneous, Ptolemaic, geostatic cosmology had collapsed.

In the second place, when Galileo mentions *motion* as one of the primary properties, he uses the term in a new sense. As Arthur Koestler remarks in *The Sleepwalkers* (1959), many things which are said and written about Galileo are not true, but there is nevertheless no doubt that he is, after all, the inventor of a theory of motion which is fundamentally distinct from the preceding, Aristotelian account (see Koestler, 1989: 358). So, when Galileo mentions motion, he refers to his own *new* theory of "local motion" (see *De Motu*, in Galilei 1809-1909: I, 243-419), which, admittedly, he only published in his *Discorsi* (1638), fifteen years after *Il Saggiatore*, but which he had already announced in his 1610 letter to Vinta. In this letter, Galileo writes that he was finishing "three books on local motion – an entirely new science in which no one else, ancient or modern, has discovered any of the most remarkable laws which I demonstrate to exist in both natural and violent movement; hence I may call this a new science and one discovered by me from its foundations" (Galilei, 1957: 63).

*Primary properties and secondary qualities?*

Galileo makes a real distinction between primary properties and secondary qualities. However, this distinction is not a distinction between sensible and non-sensible qualities, since all of Galileo's primary properties and secondary qualities, in *Il Saggiatore*, can in principle be perceived via the senses. The Italian

natural philosopher simply does not mention non-sensible qualities. But what precisely are his primary properties? At first glance, this question seems easy enough to answer, since Galileo enumerates his primary properties in the passage quoted previously: shape, size, number, location, motion or rest, and touching or not-touching another body. But what precisely are his secondary qualities, then?

Following *Il Saggiatore*'s passage that I quoted on the primary-secondary distinction, Galileo explains that he wants to make his notion clearer by means of a few examples. The first example he gives is that of touching a marble statue versus touching a living man. From the standpoint of the external object, he argues, both moves are similar. However, the live body – which receives these operations, in the second situation – feels different sensations according to the various places at which it is touched. It is noteworthy that Galileo here introduces a new word, "sensations" ("sensazioni"), instead of his earlier "affections" ("affezzioni"), "accidents" ("accidenti") or "qualities" ("qualità"). Galileo emphasizes twice that these sensations belong to the body of the perceiver and not to the external body. Galileo underlines also that there is no special faculty (or power) that could have caused the sensation, thereby rejecting the idea that there is always, in the affecting body, a kind of power that would have caused the sensation. It is well known that later, for Locke, secondary qualities will become "powers to produce ideas in us directly" (Downing, 2000: 106).

There is nothing besides moving and touching that is already in the external object, which means, for example, that when one is tickled, there is no "faculty of tickling" that causes the sensation: tickling is not in the hand that tickles. Galileo concludes from this that sensations such as tickling are not in the affecting body, but in the affected body, and that this kind of sensation has no more reality than colours, odours and flavours do. The Italian natural philosopher puts emotions like tickling in the same category as the secondary qualities ("molte qualità") he has already mentioned, namely in the category of sensible qualities such as odours, colours and sounds.

Often the "primary properties" are called "geometrical qualities", however, Max Jammer has argued that Galileo's primary properties can be divided into three groups (see Jammer, 1997: 51-52). Two of these groups are of a mathematical character: the geometrical qualities (shape, size, location, contiguity), and the arithmetic quality (number). The third group, however, is of

a physical or, more precisely, a kinematic character: motion, which – though mathematizable – is not a purely mathematical property[5]. Among Galileo's primary properties, however, there is *no* non-spatiotemporal aspect of matter. All of Galileo's "properties" are thus spatiotemporal qualities. For this reason, Dijksterhuis has called the Galilean primary properties "geometrico-mechanical properties", arguing (in *The Mechanization of the World Picture*) that, not only Galileo's primary properties, but also his secondary qualities, were mechanized *because* they were caused by a body with only mechanical properties. And indeed, this is what we find Galileo claiming: "To excite in us tastes, odors, and sounds I believe that nothing is required in external bodies except shapes, numbers, and slow and rapid movements" (Galilei, 1957: 276-277).

It is remarkable that certain properties are not listed by Galileo in the 1623 passage where he discusses properties. I will give two examples. As Giorgio de Santillana notes in his edition of the *Dialogue*: "[T]here are mathematical properties, inherent in matter; but "mass" although mathematizable is not one of them, for it is another name for matter itself and distinguishes it from abstract matter which is geometry. Physical reality and mass are two names for one and the same thing […] Hence mass [for Galileo] cannot be defined in terms of anything else; it is a primum" (Galilei, 1956: 252).

Interestingly, there is another important property not mentioned in Galileo's list of primary properties, *viz.* gravity. In his *Discourse*, the discoverer of the law of gravity writes that gravity is an intrinsic property of matter (see Galilei, 2002: 193-194[6]). So, we would expect that a piece of matter – i. e. a body – would have gravity as one of its primary properties. However, Galileo

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[5] As Kant will later remark his *Kritik der Reinen vernunft*, strictly speaking, motion is not a mathematical quality.

[6] Original text: "Stabililito dunque tal principio, Avanti che passiamo più alter, devo metter in considerazione come queste forze, resistenze, momenti, figure, etc., si posson considerar in astratto e separate dalla materia, ed anco in concreto e congiunte con la materia; ed in questo modo quelli accidenti che converrano alle fifure considerate come immateriali, riceveranno alcune modificazioni mentre li aggiugneremo la materia, ed in consequenza le gravità. [...] E però, prima che passar più oltre, è necessario che noi convenghiamo in por distinzione tra queste due maniere di considerare, chiamando un *prendere assolutamente* quello quando intenderemo lo strumento preso in astratto, cioè separato dalla gravità della propria materia; ma congiugnendo con le figure semplici ed assolute la materia, con la gravità ancora, nomineremo le figure congiunte con la materia *momento o forza composta*" (Galilei, 1809-1909: VIII, 154-155).

does not mention gravity in his 1623 list of primary properties – or indeed, of secondary qualities. So what kind of notion is Galileo's gravity, then?

Maurice Clavelin has demonstrated that Galileo never really understood the nature of gravity and specific gravity – which would only become clear with Newton's law of universal gravitation – and moreover, that he *knew* he didn't understand it (see Clavelin, 1996: 341). This is why Galileo tries to avoid the term gravity and limits himself to speaking of "falling bodies", for instance, in his *Dialogue* and *Discourse*. For Galileo, gravity is a property that all bodies have in virtue of being pieces of matter, but according to Alexandre Koyré, gravity is neither a primary property nor a secondary quality for Galileo; Koyré writes: "'gravité' n'est pas chez Galilée une qualité théorique des corps; elle est une propriété empirique; une qualité du sens commun" (Koyré, 1939: 231). Another possible reason why Galileo does not mention gravity in 1623 might be that his doctrine of properties-qualities was fundamentally anti-Peripatetic. He may only mention the properties that Aristotle mentions in his criticism towards the atomists, then, in order to underline how his distinction of primary and secondary qualities differs from – and further, reverses – Aristotles'.

*Are primary properties intrinsic properties?*

Primary properties are presented by Galileo as properties belonging to bodies-in-themselves, as opposed to secondary qualities, which we *attribute* to bodies-in-themselves. Hence, primary properties are considered to be intrinsic properties of bodies. It is nonetheless hard to define what "intrinsic" actually means in this context. If we take the intuitive definition of the term as independent from the interaction with its environment (see Marshall, 2012), then it becomes hard to maintain that Galileo's primary properties are actually intrinsic. These properties are, according to Galileo himself, intrinsic relative to our senses, but extrinsic relative to other sorts of bodies.

Let us examine Galileo's list of primary properties in more detail in order to illustrate this point. Firstly, motion or, more precisely, local motion, is relativistic in Galileo's new view. Body A, which is at rest relative to body B, can at the same time be in motion relative to body C. Moreover, according to Galilean relativity (see Galilei, 1957: 265), somebody who participates in a motion is not even able to distinguish whether he is at rest or in motion, if his frame of reference moves at the same uniform speed. So motion is, strictly

speaking, not an intrinsic property of a body. Similarly, Galileo emphasizes repeatedly in *Il Saggiatore* – as in other works (see for instance Galilei, 2002: 25) – that his other primary properties can only be completely understood in relation to other bodies. Interestingly, at the moment that Galileo mentions *size* as a primary property, he is not referring purely and simply to size. More precisely, he describes size in terms of "being large or small in comparison to other things". So, for Galileo, it only makes sense to speak about size in relation to other external bodies – which is to say that he does not regard size as an *intrinsic* property (at least not in the above-mentioned intuitive sense of the term).

Likewise, Galileo does not simply mention *touching* in his list of properties from *Il Saggiatore*, but rather "touching or not touching some other body", which clearly highlights the relative aspect of this property. Moreover, another primary property which he mentions is "situation", that is, the spatiotemporal location of a body. This is also, quite clearly, the position of an object *relative* to other bodies functioning as a frame of reference at a given point in time. Similar considerations can be made concerning *shape*, which was an important property in Galileo's defense of the irregular shape of the surface of the moon. And last but not least, there is the property *number*, "as being one in number, or few or many". Galileo emphasizes repeatedly that, generally speaking[7], numbers which are used in natural philosophy should not be understood in an absolute sense, but in a relative one. In *Il Saggiatore*, for example, he criticizes Sarsi's attacks on Guiducci, for Sarsi had argued that the enlargement of his telescope was infinite, to which Galileo replied:

> Here Sarsi rises up and, in a series of long attacks, does his best to show me to be a very poor logician for calling this enlargement infinite. At my age these altercations simply make me sick, though I myself used to plunge into them with delight when I too was under a schoolmaster. So to all this I answer briefly and simply that it appears to me Sarsi is showing himself to be just what he wants to prove me; that is, little cognizant of logic, for he takes as absolute that which is spoken relatively (Galilei, 1957: 241).

## *Exclusion of the psychical from the physical*

Scholars such as Stephen Gaukroger have written that Galileo's distinction comes down to a distinction between "qualities which bodies actually possess" and "psychic additions of the perceiving mind" (Gaukroger, 2006:

[7] For Galileo's relativism in *Il Saggiatore*, see also Galilei, 1957: 249.

326). Others, such as John L. Heilbron, have argued that the Galilean distinction differentiates between "primary qualities and the sensations they produce in our minds through our senses" (Heilbron, 2010: 251). Thus, in this view, Galileo's primary properties are physical, while secondary qualities are considered to be mental.

At first glance, this seems to be correct, since in Drake's translation of *Il Saggiatore*, which was first published in 1957 and remained for a long time (between 1957 and 2008) the only published English translation of the work, we indeed read that secondary qualities "only reside in the consciousness":

> Hence I think that tastes, odors, colors, and so on are no more than mere names so far as the object in which we place them is concerned, and that they reside only in consciousness. Hence if the living creature were removed, all these qualities would be wiped away and annihilated (Galilei, 1957: 274).

However, we find Galileo writing something quite different in the original, Italian version:

> Per lo che vo io pensando che questi sapori, odori, colori, etc., per la parte del suggetto nel quale ci par che riseggano, non sieno altro che puri nomi, ma tengano solamente lor residenza nel corpo sensitivo, sì che rimosso l'animale, sieno levate ed annichilate tutte queste qualità; tuttavolta però che noi, sì come gli abbiamo imposti nomi particolari e differenti da quelli de gli altri primi e reali accidenti, volessimo credere ch'esse ancora fussero veramente e realmente da quelli diverse (Galilei, 1890-1909: VI: 347-348).

So, in the original text, Galileo nowhere writes that secondary qualities and emotions reside "in consciousness". On the contrary, he writes that they reside "in the sensible body" ("nel corpo sensitive") or, in other words, in the body of the perceiver, whether it be a human body or an animal body. There is thus no question of Galileo referring his notion of secondary qualities to "consciousness" or to "the mental".

Maurice A. Finocchiaro is much closer to the text in his recent translation of the passage from *Il Saggiatore*, and he sees no reason to translate the passage differently:

> Thus, from the point of view of the subject in which they seem to inhere, these tastes, odours, colours, etc., are nothing but empty names; rather they inhere only in the sensitive body, such that if one removes the animal, then all these qualities are taken away and annihilated (Galileo, 2008: 185).

This newer English translation corresponds well with the only existing French translation of the same passage, which was the work of Christiane Chauviré: "Je pense donc que ces saveurs, odeurs, couleurs, etc,, eu égard au sujet dans lequel elles nous paraissent résider, ne sont que de purs noms et n'ont leur siège que

dans le corps sensitif" (Galilei, 1979: 239). Nevertheless, the most recently published English translation of this important passage, which is the work of William R. Shea and Mark Davie, translates the passage in the same sense as before, thereby rendering Galileo's "corpo sensitive" as "the mind":

> So it seems to me that taste, odour, colour, and so on are nothing more than pure names, as far as the objects in which we think they reside are concerned. Rather, they exist only in the mind that perceives them, so that if living creatures were removed, all these qualities would be wiped away and no longer exist (Galilei, 2012: 119).

Drake and Shea not only introduce a word, *viz.* "mind", which is not in the original text, but they also seem to be inconsistent in their translations elsewhere. In the paragraph that immediately follows Galileo's distinction, they once more use the same term phrasing: "living and sensitive body" ("corpo animato e sensitivo"). But this time, Drake and Shea do not translate Galileo's phrase as "consciousness" or "mind"; rather, Drake translates "coporo sensitive" as "sensitive body", while Shea uses "percipient body", which clearly emphasizes the bodily (see Galilei, 2012: 120). Clearly this is contradictory! In the first passage, both translators write that Galileo's secondary qualities reside "in the consciousness or in the mind", yet in the next passage – where Galileo actually illustrates his view with a few examples – they write that these qualities reside in the body.

The point that Galileo wants to make in the paragraph where he gives the examples is that affections and sensations, which he groups in a same category in this instance, are not properties of the external body, but are in the body of the perceiver: "This titillation belongs entirely to us and not to the feather; if the live and sensitive body were removed it would remain no more than a mere word" (Galilei, 1957: 275). Nowhere does Galileo write that the secondary qualities reside in the mind or in consciousness. Moreover, he does not use mental language or psychological explanations in the following paragraphs, in which he explains the corporeal changes that take place in an animate body at the moment that its senses are excited to cause sounds, heat, tastes, odors and colors.

Galileo was very rigorous in his exclusion of the psychic from the corporeal, which would later become an essential element of mechanistic philosophy. A good illustration can be found in his comments on Gilbert's work, which he exposes extensively at the end of the "Third Day" of his *Dialogo* (1632; see Galilei, 2001: 464-481). Galileo admired Gilbert's *De Magnete* (1600), because it was based on observations and experiments, and not on the authority

of Aristotle's texts. Galileo nevertheless regretted that the English physicist did not discuss his subjects more mathematically. However, it is remarkable that Galileo does not agree with Gilbert's explanation of magnetism in terms sympathy and antipathy. It is the spokesman of the Peripatetic philosophy, Simplicio, who points out these two elements as the cause of magnetic phenomena. However, Sagredo refutes this way of explaining magnetism and argues that *sympathy* and *antipathy* are nothing more than mere names. Moreover, Salviati does not even comment on these principles and opens up a discussion on another subject. Likewise, Salviati does not account for cohesion in the "First Day" of the *Discorsi* in terms of sympathy and antipathy (see Galileo, 2002: 55). His opponent, Simplico, remarks that he felt "almost like laughing at the great antipathy which Salviati exhibit[ed] against the use of the word antipathy" (55). What Galileo writes in his two famous dialogues does match well with what he had written much earlier in *Il Saggiatore*. In this polemic work, Galileo makes clear that the introduction of "sympathy, antipathy, occult properties, influences and other terms" is just used by "some philosophers as a cloak for the correct reply, which would be: 'I do not know'" (Galilei, 2001: 241). In sum, in contrast to Renaissance naturalists, Galileo does not apply projections of the human psyche in order to explain the mysteries of opaque nature (see Westfall, 1977: 25-42). Instead, he prefers to leave certain ultimate problems unsolved, or as lying beyond the domain of physics.

Nevertheless, by the use of the terms "sensible body", Galileo suggests that, besides the body, there is an Aristotelian, immaterial sensitive soul, which is linked with the body and which functions as a principle of distinction between human, animal, vegetative, and unliving bodies. In the same passage, he even uses, very exceptionally (i. e. only once[8]), the notion of "sensitive soul" ("l'anima sensitive") – which Drake translates by "conscious mind", which only humans and animals have. Galileo is not clear how he conceives of the relation between the mind and the body. However, he seems to suggest that the mind has a pleasant or non-pleasant emotion at the moment that tiny corpuscles ("corpicelli

[8] "Ma presa questa proposizione nel sentimento commune, sì che mossa una pietra, o un ferro, o legno, ei s'abbia a riscaldare, l'ho ben per una solenne vanità. Ora, la confricazione e stropicciamento di due corpi duri, o col risolverne parte in minimi sottilissimi e volanti, o coll'aprir l'uscita a gl'ignicoli contenuti, gli riduce finalmente in moto, nel quale incontrando i nostri corpi e per essi penetrando e scorrendo, e sentendo l'anima sensitiva nel lor passaggio i toccamenti, sente quell'affezzione grata o molesta, che noi poi abbiamo nominata *caldo*, *bruciore* o *scottamento* (Galilei, 1890-1909: VI, 352-352).

minimi") meet our body and penetrate it. At that moment, as he continues, we feel what we call "heat". Thus, the mind senses in one or another way what's going on in the body and calls this affection "heat". Consequently, secondary qualities and affections in general seem to have a corporeal as well as a mental aspect for Galileo.

*Separation of the metaphysical entities: God, Man and Nature.*

As a result of his mathematization of corporeal substance, Galileo excluded both man and God from the realm of nature. As I showed above, the corporeal domain was limited by Galileo to the domain of primary properties, which could be described in mathematical terms alone. Man, however, could not be described in mathematical terms – or, at least, not completely. For Galileo, the being of man also included the domains of color, odor, doubt, joy, etc. Man was thus understood to distinguish himself from other beings precisely by his capacity to have these sorts of affections. Man, one could say, is a bundle of secondary qualities.

As such, man was banished by Galileo from the physical world, which was, henceforth, limited to the world of moving bodies; this, at the very least, is how Edwin A. Burtt formulates it (see Burtt, 2003: 98-104). But it was not only man who was banished, for God too found himself cut off from his creation. The real world was thus limited to the world of moving bodies alone. And *motion*, in Galileo's view, was not goal-directed; on the contrary, it was understood to be fundamentally blind and aimless in nature. With final causality eliminated (which, of course, played an essential role in Aristotelian metaphysics), the concept of God also underwent a radical change. The logical outcome of Galileo's natural philosophy was that God became the first *efficient* cause, or the "great mechanical inventor".

However, between God and nature, man nevertheless retained, in a certain measure, the same middle position that he had enjoyed in traditional metaphysics and in Christian theology. On the one hand, he distinguished himself, along with animal life, from inanimate matter by having secondary qualities. On the other hand, Galileo's spokesman, Slaviati, explains, at the end of the "First Day" of the *Dialogue*, that, by his knowledge of nature, man was also capable, to a certain, limited degree, of attaining adequate knowledge of the essences of things in nature (see Galilei, 2001: 119-121). Moreover, he also held

that man was eventually capable, in contrast to other creatures, of grasping the very ideas in the intellect of God, who, as Galileo explains in his *Dialogue*, understands everything immediately.

*An earlier version of the primary-secondary distinction?*

Traditionally, leading scholars have argued that Galileo's distinction between primary properties and secondary qualities was little more than an updated version of the distinction found in ancient atomism. This is one of the reasons why Galileo's work on primary and secondary qualities has not drawn that much attention in the secondary literature. We find Heilbron adopting this position in his biography; for instance:

> In the special vocabulary applied to Galileo's distinctions, motion, shape, and size are "primary qualities" and the sensations they produce in our minds through our senses, "secondary qualities". The distinction goes back to the ancient atomists whose theory Aristotle had rejected for a fistful of good, though not unanswerable arguments (Heilbron, 2010: 251).

And indeed, early atomists like Democritus[9] did in fact account for natural phenomena (such as heat, for example) in terms of the mechanical properties of a body's indivisible parts, or atoms. Moreover, Galileo does seem to reproduce the Democtritian view, which was also espoused by Lucretius (*ca.* 99 B.C.-*ca.* 55 B.C.) and Epicurus (341 B.C.-270 B.C.), although, instead of using the term "atom" in *The Assayer*, he uses terms such as "corpicelli minimi" or "minimi ignei", etc. A closer look, however, reveals that Galileo's doctrine is not just an updated version of the ancient, atomist distinction. On the contrary, there are a number of significant differences that need to be drawn out.

First of all, Galileo does not initially explain the qualities of bodies in terms of the mechanical properties of their composite parts (or atoms). When he defines the primary properties of bodies in the passage quoted above from the text of 1623, he refers simply to the intrinsic properties of the body as such, and not of its parts.

Secondly, we find a similar distinction being made by Galileo in a much earlier work, and in this case too, the notion of the atom is never mentioned.

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[9] "By convention there are sweet and bitter, hot and cold, by convention there is color; but in truth there are atoms and the void" (Democritus, frag. 9, quoted by Kahn, 2001: 688).

The distinction appears in a bundle of letters entitled *Lettere Solari* [10] (1613), which were published ten years before *Il Saggiatore* (1623) and three years after the publication of the *Sidereus Nuncius* (1610). As such, we should at least consider the possibility of a non-atomist origin of Galileo's distinction between primary properties and secondary qualities. Galileo's correspondence with Apelles, pseudonym of the Jesuit professor Christopher Scheiner (*ca.* 1573-1650), via an intermediary, Mark Welser (1558-1614), is concerned with the nature of sunspots. In the third letter, Galileo asks the philosophical question of how adequate knowledge of things in general can be attained. In an article dealing with this text, Margaret J. Osler argues that Galileo's doctrine of qualities and his new concept of motion are both reflections of the move from essentialism to non-essentialism (see Osler, 1973). And indeed, Galileo skips over the question of internal essences ("l'essenza vera ed intrinseca delle sustanze naturali") in his discussion. Obviously, this is, yet again, a reaction against a more traditional way of doing natural philosophy. Trying "to penetrate the true and internal essence of natural substances" is, according to Galileo, far too complicated:

> But in my opinion we need not entirely give up contemplating things because they are remote from us, unless we have indeed determined that it is best to defer every act of reflection in favor of other occupations. For in our speculating we either seek to penetrate the true and internal essence of natural substances ["l'essenza vera ed intrinseca delle sustanze naturali"], or content ourselves with a knowledge of some of their properties. The former I hold to be as impossible an undertaking with regard to the closest elemental substances as with more remote celestial things. The substances composing the earth and the moon seem to me to be equally unknown, as do those of our elemental clouds and sunspots. I do not see that in comprehending substances near at hand we have any advantage except copious detail; all the things among which men wander remain equally unknown, and we pass by things both near and far with very little or no real acquisition of knowledge. When I ask what the substance of clouds may be and am told that it is a moist vapor, I shall wish to known in turn what vapor is. Peradventure I shall be told that it is water, which when attenuated by heat is resolved into vapor. Equally curious about what water is, I shall then seek to find that out, ultimately learning that it is fluid body which runs in our rivers and which we constantly handle. But this final information about water is no more intimate than what I knew about clouds in the first place; it is merely closer at hand and dependent upon more of the senses. In the same way I know no more about the true essences ["vera essenza"] of earth or fire than about those of the moon or sun, for that knowledge is withheld from us, and is not to be

[10] The most recent English translation will be found in: Galilei and Scheiner, 2010.

> understood until we reach the state of blessedness ["stato di beatitudine"] (Galilei, 1957: 123-124; original text in Galilei, 1890-1909: V, 187-188).

The fact that the true essences of things in general are only reserved for a "state of blessedness" does not mean that we are unable to acquire a suitable and ever-further advancing knowledge of things, as Galileo argues. On the contrary! According to the author of the *Sidereus Nuncius* (1610), it is possible to attain an adequate knowledge of things. Moreover, the fact that certain phenomena (such as sunspots) are remote from us does not mean that this poses a serious or novel epistemological challenge. As Galileo asks, "was not the spherical shape of the moon discovered long before that of the earth, and much more easily?"

But how are we to go about acquiring such adequate knowledge? In answer to this question, Galileo proposes that we focus our attention on what he calls "some properties" of these psychical phenomena, namely the properties of location ("il luogo"), motion ("il moto"), shape ("la figura"), size ("la grandezza"), opacity ("l'opacità"), mutability ("la muabilità"), generation ("la produzione"), and dissolution ("il dissolvimento"). These properties clearly have a certain priority for Galileo, for they are observable and (therefore) knowable, and they function as the basis of other "more controversial qualities of natural substances" ("più controverse condizioni delle sustanze naturali"):

> But if what we wish to fix in our minds is the apprehension of some properties of things, then it seems to me that we need not despair of our ability to acquire this respecting distant bodies just as well as those close at hand – and perhaps in some cases even more precisely in the former than in the latter. Who does not understand the periods and movements of the planets better than those of the waters of our various oceans? Was not the spherical shape of the moon discovered long before that of the earth, and much more easily? Is it not still argued whether the earth rests motionless or goes wandering, whereas we know positively the movements of many stars? Hence I should infer that although it may be vain to seek to determine the true substance of the sunspots, still it does not follow that we cannot know some properties of them, such as their location, motion, shape, size, opacity, mutability, generation, and dissolution. These in turn may become the means by which we shall be able to philosophize better about other and more controversial qualities of natural substances. And finally by elevating us to the ultimate end of our labors, which is the love of the divine Artificer ["del divino Artefice"], this will keep us steadfast in the hope that we shall learn every truth in Him, the source of all light and verity (see Galilei, 1957: 124; original text in Galilei, 1890-1909: V, 188).

Here we find Galileo establishing a distinction between two series of qualities. The resemblance between this list of properties and the list that he will offer in his 1623 text, *Il Saggiatore*, is striking. Just as in this text, he mentions location,

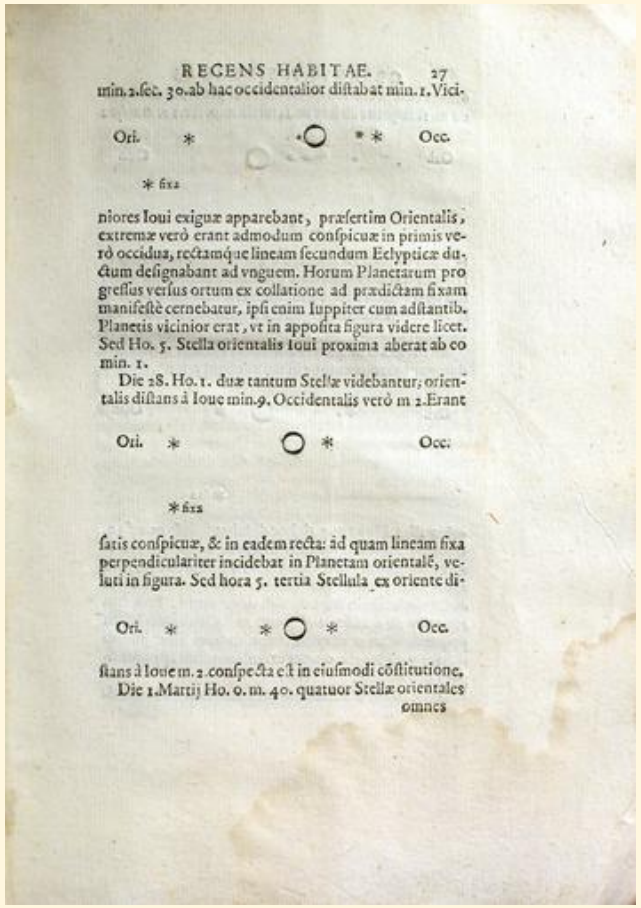
motion, shape and size, to which he adds the qualities of opacity, mutability, generation, and dissolution, since these are of particular interest in his discussion of sunspots. It is evident, moreover, that these additional qualities are consistent with the other, later list.

On the basis of these passages, it is clear that Galileo had already set up a distinction between primary properties and secondary qualities much earlier than *Il Saggiatore*. Moreover, in his 1613 letters, it is important to note that he does not limit himself merely to mentioning or applying this distinction; on the contrary, he explains it explicitly in the very same moment that he philosophizes about the basis of knowledge of bodies in general. And quite strikingly, in this discussion, atomism is not mentioned, although we know that Galileo was more than sufficiently familiar with the theory by 1613. There is ample historical evidence that, in or around 1612, he was in discussion with the Peripatetic, La Galla, as well as others, on the atomistic doctrine of qualities, which he opposed to the Peripatetic views (see Crombie, 1967: 71-91).

It is not only in his *Lettere Solari* of 1613 that Galileo applies his distinction between primary properties and secondary qualities, for we find this distinction showing up in his *Sidereus Nuncius* of 1610 as well. In the accounts that he gives of his observations, he only mentions primary properties – colours, for instance, are almost entirely absent from his descriptions. These observations, which ultimately led to the collapse of the traditional notion of the cosmos, were observed, described and analysed by Galileo solely in terms of primary properties. This is true of his observations concerning the position of the Jupiter's satellite moons, the irregular shape of the surface of our own moon, the shape, size and movement of sunspots, the shape of Saturn, etc. Time and again, he translated physical phenomena into the mathematical language of primary properties, without, however, transforming a physical problem directly into a mathematical problem.

Interestingly, Galileo put his doctrine of primary properties and secondary qualities to use not only in his writings, but also in the images that he skilfully fashioned for his *Sidereus Nuncius* and the *Lettere Solari*. Horst Bredekamp and Mario Biagoli both distinguish between two different kinds of images in Galileo's work: diagrammatical images and realistic images (see Bredekamp, 2009 and Biagioli, 2006). In both cases, the most important element is clearly the sort of property that Galileo would later describe as primary – other qualities are excluded from the depiction. In the realistic image of the

moon, for instance, it is the shape of the moon's surface that is important. In the diagrammatic image of Jupiter, on the other hand, the relative locations of Jupiter and its satellites are pictured. Similarly, in the images of the sunspots, it is the motion, shape and size of the spots that Galileo draws attention to.



REGENS HABITAE. 27

min. 2. sec. 30. ab hac occidentalior distabat min. 1. Vici-

Ori. * ○ * * Occ.

* fixa

niores Ioui exiguæ apparebant, præsertim Orientalis, extremæ verò erant admodum conspicuæ in primis verò occidua, rectamque lineam secundum Eclypticæ ductum designabant ad vnguem. Horum Planetarum progressus versus ortum ex collatione ad prædictam fixam manifestè cernebatur, ipsi enim Iuppiter cum adstantib. Planetis vicinior erat, vt in appositа figura videre licet. Sed Ho. 5. Stella orientalis Ioui proxima aberat ab eo min. 1.

Die 28. Ho. 1. duæ tantum Stellæ videbantur; orientalis distans à Ioue min. 9. Occidentalis verò m 2. Erant

Ori. * ○ * Occ.

* fixa

satis conspicuæ, & in eadem recta: ad quam lineam fixa perpendiculariter incidebat in Planetam orientalē, veluti in figura. Sed hora 5. tertia Stellula ex oriente di-

Ori. * * ○ * Occ.

stans à Ioue m. 2. conspecta est in eiusmodi cōstitutione.

Die 1. Martij Ho. 0. m. 40. quatuor Stellæ orientales omnes


Fig. 1. Diagrammatical pictures from the *Sidereus Nuncius* (1610). Left: the relative position of the satellites of Jupiter; right: the relative position of the Pleiades.

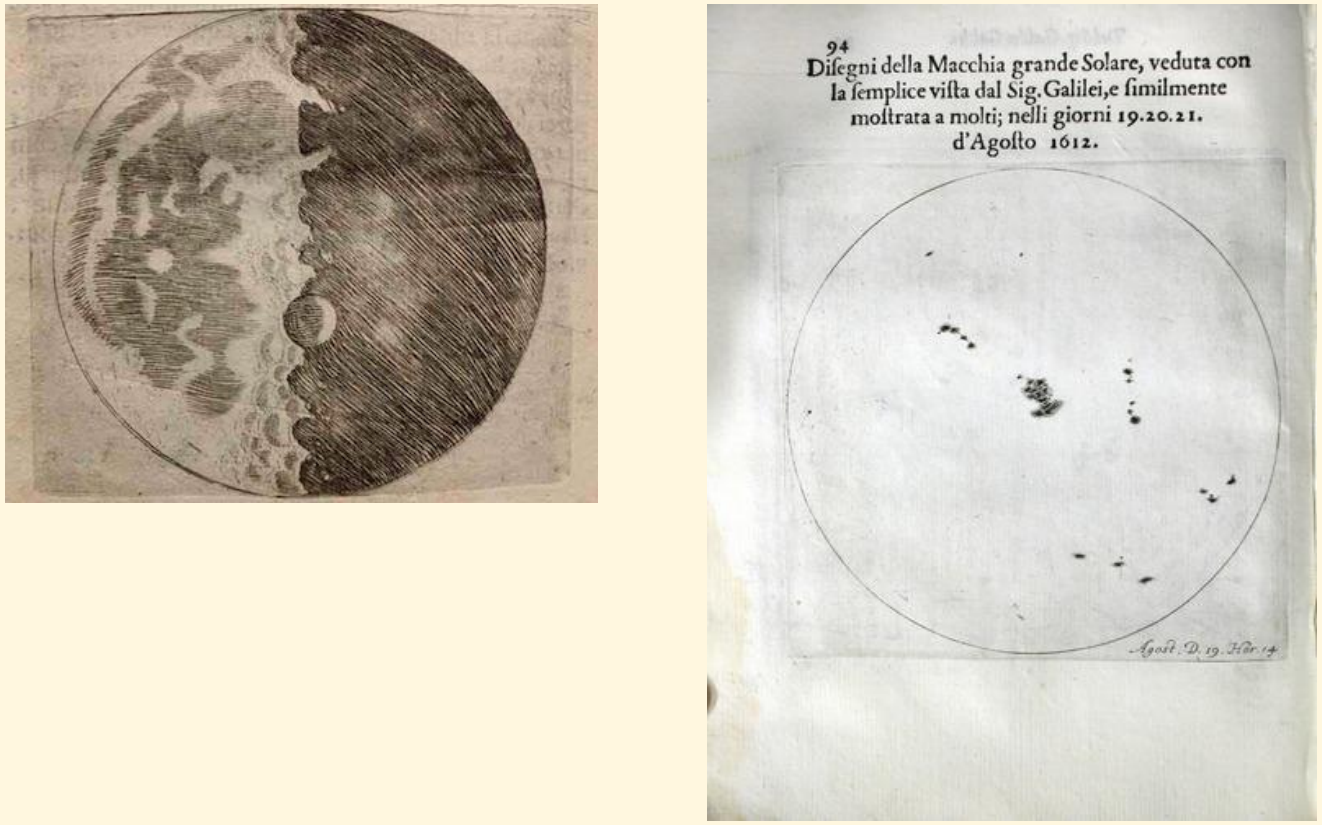



Fig. 2. Realistic pictures. Left : the sunspots (*Lettere Solari*, 1613); right: the irregular surface of the moon (*Sidereus Nuncius*, 1610).

*The definition of the body and transubstantiation*

As a final point of interest, it is important to note that Galileo's doctrine of qualities is likely to have played a crucial role in the iconic Galileo Affair. According to the Italian historian Pietro Redondi, the real reason why Galileo was condemned by the Vatican had much less to do with his defence of Copernicanism than it did with his doctrine of qualities, which no longer allowed for an explanation of transubstantiation in the sacrament of the Eucharist (see Redondi, 1983). This was, of course, an extremely important question in the period of the Counter-Reformation (see Armogathe, 2007), that is, following the Council of Trent (1545-1563). Redondi bases his thesis on a document that he discovered in the Inquisition archives in Rome. This unsigned and undated document was a complaint against the author of *Il Saggiatore*, whose theory of "atomism" undermined the doctrine of transubstantiation and the Eucharist.

According to Catholic dogma, which was reformulated during the Council of Trent, the bread and wine were understood to be transformed in the celebration of the Eucharist into the body and blood of Christ. For the scholastics (see Stengers, 1997 and Chareix, 2002: 109-122), it had been possible to hold that there could be a change in *substance* without a corresponding change in appearance, for the notions of *substance* and *accident* had been based on a theory of substantial forms and real qualities. However, according to Galileo's new doctrine, the mechanical/causal relation between primary properties ("substance") and secondary qualities ("accident") rendered this way of accounting for the Eucharist impossible (see Chareix, 2002: 111). Galileo makes a rather indirect and prudent allusion to transubstantiation in the "First Day" of his *Dialogo* when he writes that he was "never thoroughly convinced of any transmutation of substance understood (always confining ourselves to strictly natural phenomena) according to which matter becomes transformed in such a way that it is utterly destroyed, so that nothing remains of its original being, and another quite different body is produced in its place" (see Galilei, 2001: 45). In the place of a theory concerning transformed substances, he proposes a corpuscular explanation for the various aspects of bodies.

Maurice A. Finocchiaro writes in the epilogue of *Retrying Galileo* (2002) that a scholarly consensus has emerged that regards Redondi's account as untenable (see Finocchiaro, 2002: 362-363). In spite of this, he nevertheless argues that the Redondi controversy was "too short lived". It stands to reason

that the two elements of Galileo's account – *viz.* atomism and Copernicanism – would have both played a significant role in Galileo's condemnation, much as they would, later on, in Descartes' condemnation (see Armogathe, 2001), since they were both regarded by the Church as anti-Peripatetic and heretical (see Greenblatt, 2011). As Heilbron puts it: "Although Galileo's trial was not about atomism, astrology, freewill, salvation, grace, or divine attributes, many or all of them probably were in Urban's mind when he castigated Galileo's doctrine as 'the worst [menace] ever perceived'" (Heilbron, 2010: 308).

*Bibliography*

Anstey, Peter R. (2000). *The Philosophy of Robert Boyle*. Oxford: Routledge.

Aristotle (1984). *Sense and Sensibilia*. In *The Complete Works of Aristotle. The Revised Oxford Translation*, trans. by John Isaac Beare, ed. by Jonathan Barnes, vol. 1, p. 693-713. Princeton: Princeton University Press.

Armogathe, Jean-Robert (2001), "La première condamnation des oeuvres de Descartes, d'après des documents inédits aux archives du Saint-Office". In *Nouvelles de la République des Lettres* 2: 103-137.

——— (2007). *La nature du monde. Science nouvelle et exégèse au XVII^e siècle*. Paris: Presses universitaires de France.

Biagioli, Mario (2006). *Galileo's Instruments of Credit. Telescopes, Images, Secrecy*. Chicago and London: University of Chicago Press.

Bredekamp, Horst (2009). *Galilei der Künstler*. Berlin: Akademie Verlag.

Burtt, Edwin A. (2003). *The Metaphysical Foundations of Modern Physical Science. A Historical and Critical Essay*. Mineola and New York: Dover Publications.

Chareix, Fabien (2002). *Le mythe Galilée*. Paris: Presses universitaires de France.

Clavelin, Maurice (1996). *La philosophie naturelle de Galilée*. Paris: Albin Michel.

Crombie, Alistair Cameron (1967). "The Primary Properties and Secondary Qualities in Galileo Galilei's Natural Philosophy". In *Saggi su Galileo Galilei*, ed. by Carlo Maccagni: 71-91. Florence: G. Barbera.

Downing, Lisa (2000). "Locke. The primary and secondary quality distinction". In *The Routledge Companion to Metaphysics*, ed. dir. by R. Le Poidevin: 98-108. Oxford: Routledge.

Drake, Stillman and Charles D. O'Malley (1960). *The Controversy on the Comets of 1618*. Philadelphia: University of Pennsylvania Press.

Finocchiaro, Maurice A. (2007), *Retrying Galileo. 1633-1992*. Berkeley, Los Angeles, and London: University of California Press.

Galilei, Galileo (1890-1909). *Le opere di Galileo Galilei. Edizione nazionale sotto gli auspicii di sua maesta il re d'Italia*, ed. by Antonio Favaro *et al.*, 21 vols. Florence: G. Barbara.

——— (1956). *Dialogue on the Great World Systems*, trans. and ed. by G. de Santillana. Chicago: Chicago University Press.

——— (1957). *Discoveries and Opinions of Galileo*, trans. by Stillman Drake. New York: Anchor Books.

——— (1979). *L'essayeur*, trad. par Christiane Chauviré. Paris: Les Belles Lettres.

——— (2001). *Dialogue Concerning the Two Chief World Systems*, trans. and ed. by Stillman Drake. New York: Modern Library.

——— (2002). *Dialogues Concerning Two New Sciences*, ed. by Stephen Hawking. Philadelphia and London: Running Press.

——— (2005). *Il Saggiatore*, ed. by Ottavio Besomi and Mario Helbing. Rome and Padova: Antenore.

——— (2008). *The Assayer*. In *The Essential Galileo*, trans. by Maurice A. Finocchiaro: 179-189. Indianapolis and Cambridge: Hackett Publishing Company.

——— (2012). *Selected Writings*, trans. by William R. Shea and Mark Davie. Oxford: Oxford University Press.

——— and Christopher Scheiner (2010). *On Sunspots*, trans. by Eileen Reeves and Albert van Helden. Chicago and London: University of Chicago Press.

Gaukroger, Stephen (2006), *The Emergence of a Scientific Culture*. Oxford: Oxford University Press.

Greenblatt, Stephen (2011). *The Swerve. How the World Became Modern*. New York: W. W. Norton & Company.

Heilbron, John L. (2010). *Galileo*, (Oxford: Oxford University Press, p. 251).

Hume, David (1992). *Treatise on Human Nature*. New York: Prometheus Books.

Jammer, M. (1997). *Concepts of Mass in Classical and Modern Physics*. Mineola and New York: Dover Publications.

Kahn, Charles H. (2001). "History of Western Ethics. I. Presocatic Greek". In *Encyclopedia of Ethics*, ed. by Lawrence C. Becker and Charlotte B. Becker: 686-690. Abingdon and New York: Routledge.

Koestler, Arthur (1989). *The Sleepwalkers*. London: Penguin Books.

Koyré, Alexandre (1939). *Études galiléenne. Galilée et la loi d'inertie*. Paris: Hermann.

Marshall, Dan (2012). "Intrinsic versus extrinsic properties". In *Stanford Encyclopedia of Philosophy*, ed. by Edward N. Zalta: http://plato.stanford.edu/entries/intrinsic-extrinsic. Stanford: Stanford Center for the Study of Language and Information.

Nolan, Lawrence (2011). *Primary and Secondary Qualities. The Historical and Ongoing Debate*. Oxford: Oxford University Press.
Osler, Margaret J. (1973). "Galileo, Motion, and Essences". *Isis* 64 (4): 504-509.
Redondi, Pietro (1983). *Galileo eretico*. Torino: Einaudi.
Shea, William R. (1991). *The Magic of Numbers and Motion. The Scientific Career of René Descartes*. Canton, Mass.: Watson Publishing International.
Stengers, Isabelle (1997). "Les affaires Galilée". In *Éléments d'histoire des sciences*, ed. by Michel Serres: 223-273. Paris: Bordas.
Westfall, Richard S. (1977). *The Construction of Modern Science. Mechanisms and Mechanics*. Cambridge: Cambridge University Press.

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