Historians of Science, Creators. Philosophical Perspectives on the History of Science on the light of *Il Saggiatore* by Galileo Galilei

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To William R. Shea,
sage, wise, and yet Galilean.

But the narrators are not only witnesses – least of all are they witnesses; they are actors and makers.

(Svjatlana Aleksievič, *The unwomanly face of war: an oral history of women in World War II*, New York, Random House, 2017, xxi).

1. Introduction

Galileo Galilei expresses his appreciation for the "istorie, cioè le cose sensate", referring to meaningful histories, writing to Giovanfranc-

1 An earlier version of this paper was presented at the Congress *Reading the Book of Nature Across Science, History and Philosophy. To Celebrate 400th Anniversary of Galilei's* "Il Saggiatore", organized jointly by the Italian Society of History of Science, the Italian Society for Logic and the Philosophy of Science, and the Italian Philosophical Society in Florence, 28-30 June 2023. In that context, I sought to propose a reflection that, beginning with Galileo's *Il Saggiatore*, aimed to examine key points of convergence and intersection between the history of science, the history of philosophy, and the philosophy of science. Recognizing that this objective is too ambitious to be fully realized within a single essay, I have endeavored to frame the discussion in a way that fosters new avenues for collaboration. I am grateful to Elena Canadelli, Davide Pietrini, Vincenzo Fano, William Shea, and Ugo Baldini for the valuable discussions during the preparation phase of this paper. Any errors or inaccuracies remain my sole responsibility.

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esco Buonamici[2]. He references reports from mariners traveling the globe as valuable sources for understanding natural phenomena, such as the ebb and flow of tides. It was the year 1629, November 19th, and he was preparing his "dialogi" (which will become the *Dialogo sopra i due massimi sistemi del mondo*), in which he aimed to explain[3]:

> La vera cagione, lontanissima da tutte quelle cose alle quali è stato sin qui attribuito cotale effetto.
>
> [The true cause, very different from all those things to which such an effect has hitherto been attributed.]

For Galileo, narratives of natural facts serve as critical tools within the framework of *historia naturalis*, aiding the investigation of causes central to natural philosophy. His writings suggest that historical accounts act as necessary mediators for uncovering the physical nature of phenomena, such as tides. However, Galileo's regard for narratives surfaces in a more articulated manner in *Il Saggiatore* (1623)[4], his celebrated polemic against the Jesuit Orazio Grassi on the nature of comets. Addressed to Virginio Cesarini, this text culminates Galileo's dispute with Grassi and displays his literary proclivities. Galileo fills his writings with references to "men of letters" or "historians" among which Dante, Giovanni Ciampoli, Carlo Dati, Anton Francesco Doni,

2 Galileo Galilei to Gianfrancesco Buonamici, 19 November 1629, in Galileo Galilei, *Opere. Edizione nazionale*, Antonio Favaro (ed.), Firenze, Barbèra, 1890-1909 (rist. 1919), 20 voll. (*Edizione nazionale* hereafter), vol. xiv, pp. 52-55: 54.

3 *Ibidem*.

4 Galileo Galilei, *Il Saggiatore: nel quale con bilancia esquisita e giusta si ponderano le cose contenute nella Libra astronomica e filosofica di Lotario Sarsi*, appresso Giacomo Mascardi, Roma, 1623. Partial English translation in *The Assayer*, in *Discoveries and opinions of Galileo*, translated with an introduction and notes by Stillman Drake, New York, Doubleday Anchor Book, 1957, pp. 231-280. In this paper I will refer also to other editions: *Edizione nazionale*, vol. vi, pp. 197-372; Id., *Il Saggiatore*, edited and commented by Ottavio Besomi and Mario Helbing, Roma-Padova, Antenore, 2002; Id., *Il Saggiatore*, edited and commented by Michele Camerota and Franco Giudice, Milano, Hoepli, 2023.

Giovanni Pontano, and, above all, Ariosto. Grassi, in turn, cited classical authors like Ovid, Lucretius, Lucan, and Virgil. Virgil's character Mezentius, for example, illustrated the Aristotelian idea that an arrow's ferrous body is heated by friction with the air (*attrizione*[5]), a notion Grassi deemed relevant to his inquiry. Galileo, however, protested the use of poetic authority over empirical evidence[6]:

> Voi contrastate coll'autorità di molti poeti all'esperienze che noi produciamo. [You contrast with the authority of many poets the experience we produce].

However,

> se quei poeti fussero presenti alle nostre esperienze, muterebbono opinione, e senza veruna repugnanza direbbono d'avere scritto iperbolicamente o confesserebbono d'essersi ingannati.
>
> [If those poets were present to our experiences, they would change their opinion, and without hesitation they would say that they had written hyperbolically or confessed that they had been mistaken].

For Galileo, empirical experience – repeatable and independent of poetic narratives – forms the foundation of knowledge. Specific epistemic principles govern such experiences: the necessity of experimental verification, rejection of authority, openness in scientific inquiry, reliance on instruments, and the standardizing role of mathematics in understanding nature.

In *Il Saggiatore*, Galileo integrates experience and narrative as dual pillars of epistemology, welcoming scientific creativity within a disciplined framework. Hypotheses, ideas, and interpretations flourish in this space while nature is "narrated." Galileo's meticulous storytelling reflects his dual role as a collector of data and a theorist of knowledge. Yet here, Galileo writes amid uncertainty. He has no definitive theory of comets but dismantles Grassi's arguments, rooted in Tycho Brahe's

5 Galileo, *Il Saggiatore*, in *Edizione nazionale*, p. 339.

6 Ivi, p. 337.

geo-heliocentric model, to protect the Copernican system from misconceptions that might mislead philosophers and theologians.

Il Saggiatore of Galileo brings out a fortunate conjuncture between the need to reason about natural phenomena in their narrative-rich framework and the need to detect the fundamental epistemological cores of the philosophy of nature. Conversely, certain epistemic beliefs guide historical, literary, and narrative accounts, giving the latter a robust communicative capacity. In Galileo, it is a circular relationship in the most virtuous sense possible. To actualize this circularity, it is also necessary to speak of tension. Indeed, the question is how recomposing and treating disciplinary tenets of the history of science and philosophy of science, at first glance, are so different. History of science does not like univocal explanations, prefers complex explanations, accepts correlations, leaves room for contingent events, is very attentive to the social as well as the economic and political context, is annoyed by excessively neo-positivist descriptions, does not hesitate to link the objectivity of the data to the subjectivity of the scientist who scrutinizes it, feels the urge to make that scrutiny an "interpretation" before any explanation or description. This set of methodological attitudes would seem very distant from an image of scientific activity of a rationalistic kind, understood as a search for universal and reductivist explanations, as empirical practices aimed at the search for objectivity, and as a set of assertions. On the one hand, the historical turn in philosophy of science has made history the place to draw elaborate models of scientific development and forms of rationality, creating an alternative image of science[7]. Historiographical research has helped philosophy

7 Thomas Kuhn, Norwood Hanson, and Paul Feyerabend challenged Karl Popper's attempt to establish a logic of scientific discovery. Popper, opposing both essentialism and instrumentalism, replaced verification with falsification, arguing that scientific knowledge is best understood through its historical development. Rejecting the linear, cumulative model of science proposed by Rudolph Carnap, Hans Reichenbach, and Ernest Nagel – formalized in Carl G. Hempel's nomological-deductive model – Popper advocated for a process of conjecture and refutation, distinguishing discovery from justification. The "historical turn" in the philosophy of science emerged in opposition to this separation. For an introduction

clean up the philosophical lens with which to view science in history, with eyes purged of metascientific and para-philosophical biases[8]. On the other hand, historians have shown epistemic symptomatology as to renew entire lines of inquiry. In other words, philosophical practice has helped historians improve historiographical accounts, as also seen in the intersections of history of philosophy and theoretical philosophy. In this sense, philosophical practice helps the historian to be faithful to her vocation: that of never lingering on rigid accounts, of exploring sources and documents with a spirit of innovation and new issues, of tracing lines of continuity and identifying setbacks in disseminating intellectual schemes.

This paper reflects on the interplay between history, philosophy, and science, drawing insights from *Il Saggiatore* and going to today's practices in history and philosophy of science. Section 2 introduces Galileo's masterpiece in light of its relevance to this purpose. Section 3 examines three focuses of the history of science evident in Galileo's work and inside the historical work: the narrative dimension, the engagement with material sources, and the epistemological foundations of scientific inquiry. Section 3 concludes by suggesting a possible framework for integrating these domains, aiming to map their reciprocal interactions without succumbing to superficial hybridizations. Instead, this approach seeks to identify "common denominators" that support robust interdisciplinary research. *Il Saggiatore* proves invaluable for such an endeavor, offering a rich case study of intellectual synthesis.

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and overview to this topic, see THOMAS NICKLES, *Historicist Theories of Scientific Rationality*, in Edward N. Zalta (ed.), *The Stanford Encyclopedia of Philosophy* (Spring 2021 Edition),= <https://plato.stanford.edu/archives/spr2021/entries/rationality-historicist/>.

8 NORWOOD RUSSELL HANSON, *The Irrelevance of History of Science to Philosophy of Science*, in «Journal of Philosophy», 59(21), 1962, 574-586. See JUTTA SCHICKORE, *The Significance of Re-Doing Experiments: A Contribution to Historically Informed Methodology*, in «Erkenntnis», CXXV, 3, *What (good) is historical epistemology?*, November 2011, pp. 325-347.

2. Galileo, Grassi, and the importance of the comets

Three comets appeared, particularly big and brilliant, in the sky from the November 1618 to January 1619[9]. The phenomenon caused great excitement and curiosity, and many books on astronomical and astrological topics were produced. Unfortunately, Galileo was ill and could not devote himself to observation. Still, many friends, especially from the circles of the Accademia dei Lincei, urged him to have his say, precisely by commenting on some of the circulating texts. In particular, Galileo's attention was drawn to the 1619 volume of the Jesuit Oratio Grassi, the *Disputatio astronomica*[10]. Grassi taught at the Roman College and was known for mathematical expertise, skills as an architect, and great erudition. In the *Disputatio* he interpreted the comet as Tycho Brahe had done in 1577. Since he was unable to detect a good parallax measurement, Grassi placed the celestial object above the Moon and, most importantly, confirmed it as a real object. Grassi's thesis must have been read as support for the system and the figure of Tycho to attack Copernicus' astronomical proposal, if the prelate Giovanni Battista Rinuccini thus wrote from Rome[11]:

> I Gesuiti n'hanno pubblicamente fatto un Problema, che si stampa, e tengono fermamente che sia nel cielo; et alcuni fuora de' Gesuiti spargono voce che questa cosa butta in terra il sistema del Copernico e che egli non ha il maggior contrario argomento di questo: però s'io dicessi a V.S. che mi par mill'anni di saper l'opinion sua, credo che me lo perdonerà.
>
> [The Jesuits discussed the comet in a public lecture now in press, and they firmly believe that it is in the heavens. Some outside the Jesuit Order are spreading the rumour that it is the greatest argument against Coperni-

9 See William R. Shea, *Galileo's intellectual revolution*, London-Basingstoke, Macmillian Press, 1972, pp. 75-106.

10 Orazio Grassi, *De tribus cometis anni MDCXVIII disputatio astronomica*, Roma, ex Typ. Iacobi Mascardi, 1619. See also Id., *De tribus cometis...*, in *Edizione nazionale*, vol. vi, pp. 21-35.

11 Gio. Battista Rinuccini to Galileo, 2 March 1619, *Edizione nazionale*, vol. xii, p. 443. Translation by Shea, *Galileo's intellectual revolution*, p. 75.

cus' system and that it knocks it down. Yet, if I were to say to Your Lordship that I long a thousand years to know your opinion, I trust you would forgive me].

Under the name of a disciple, Mario Guiducci, consul of the Florentine Academy, Galileo published a *Discorso delle comete*[12] in which he insisted that those who wished to use parallactic motion to determine the position of a comet, as Tycho did, must first demonstrate that it is a physical body and not an optical phenomenon. For his part, Galileo was ready to argue that the comet was an apparent phenomenon, the result of refractive effects of sunlight, and comparable to haloes, rainbows, parhelia, and rays of sunlight streaming through clouds. According to Grassi this was not sustainable, however, because comets appeared in different positions not only with respect to the observer but also with respect to the Sun.

The controversy began here. Galileo focused on more than just the technical problem of determining parallax, e.g., how this measurement should be determined or its problematic assumptions. He gradually steered further discussions about broader themes. Cross-referencing the contents of the *Disputatio* and the *Discorso*[13], the questions were taken head-on by Galileo. Thus, far from being a compelling problem of astronomy, the discussion became a problem of the philosophy of nature. And as a result, relations with the Jesuits, of course, suffered.

12 *Discorso delle comete di Mario Guiducci fatto da lui nell'Accademia fiorentina nel suo medesimo consolato*, Firenze, Stamperia di Pietro Cecconcelli, 1619. See also *Discorso delle comete: con alcuni frammenti ad esso attinenti*, in *Edizione nazionale*, vol. VI, pp. 37-108. See also Galileo Galilei, Mario Guiducci, *Discorso delle comete*, in Galileo Galilei, Mario Guiducci, *Discorso delle comete*, edizione critica e commento a cura di Ottavio Besomi e Mario Helbing, Roma-Padova, Editrice Antenore, 2002, pp. 111-248.

13 Ottavio Besomi, Mario Helbing, *Introduzione* al *Discorso delle comete*, in Galileo Galilei, *Il* Saggiatore, cit., pp. 23-25.

Given the weakness of Galileo's position, the reaction to his *Discorso* was swift. In the *Libra astronomica ac philosophica* (1619)[14], Grassi "weighed" Galileo's opinions. Grassi expressed his ideas by pretending to have a student whose name was an anagram of Horazio Grassi Savonensi: Lothario Sarsi Sigensani. He reminded his readers of the recent condemnation of Copernicus by the Holy Office. It was unfortunate because a political problem clouded his timely criticism of Galileo. He would return to problems related to the determination of parallax or Galileo's ambiguous attitude when he remained vague or contradictory in his arguments against the Aristotelians – or rather, the Tychonians. Besides, Kepler had also tried to place the comet along a straight trajectory but had failed to dispel all doubts.

It was impossible for Tycho think about the cometary trajectories as parabolic. Thus, he supposed that they displayed a path similar to those of planets, full of retrogressions and stationary points. Yet a fruitful difference was that, if in opposition, comets did not move in retrograde directions. Consequently, it was possible to maintain immobile the Earth and invent a mixt system, as he did. Therefore, the problem of comets challenged Copernicanism and was relevant to the great astronomical treatise (which became the *Dialogo sopra i due massimi sistemi del mondo*[15]).

This tenuous explanation stood little chance of being accepted unless he could show that Tycho had been completely wrong in what he stated about comets. Galileo sought to achieve this by attacking Tycho on several fronts, and by using his consummate ability as a controversialist to destroy Tycho's prestige[16].

14 Orazio Grassi, *Libra astronomica ac philosophica qua Galilaei Galilaei opiniones de cometis a Mario Guiducio in Florentina Academia expositae, atque in lucem nuper editae, examinantur a Lothario Sarsio Sigensano*, Perugia, ex Typographia Marci Naccarini, 1619. Besides, in *Edizione nazionale*, vol. vi, pp. 109-180.

15 Galileo Galilei, *Dialogo sopra i due massimi sistemi del mondo*, in *Edizione nazionale*, pp. 21-520. Besides, Id., *Dialogue on the two greatest world systems*, translated by Mark Davie, introduction and notes by William R. Shea, Oxford, Oxford University Press, 2022.

16 William R. Shea, *Galileo's intellectual revolution*, p. 87. See also ivi, pp. 83-87.

Galileo also refused to consider an expansion of the dimensions of the universe within which to accommodate parallactic evidence. The latter refusal implied that the idea of a world small enough for the parallel displacement of distant stars to be perceptible in the event that the Earth moved. Galileo was “so intent on refuting Tycho” that he left opened the ambiguity of a world where there would be no room for heliocentric theory. Unless the stars were at an enormous distance, the absence of annual parallax was a convincing argument for Earth’s immobility. “Fear of a dangerous rival turned Galileo into a biased critic, and one wonders whether, in the heat of the debate, he hoped to dislodge the comet from the sky by demolishing Tycho’s reputation on Earth”[17]. The critical point of Galileo’s position, however, was wanting to deny that the comet was a real body[18].

3. Expectations on the history of science: kinds of creation

3.0 If historians of science “create” something

Can the construction of a worldview unfold through the stages of sourcing, understanding, and interpreting written and material sources? The historian’s work not only engages with specific problems but also expands into broader reflections on the value of science itself. This vision is continually reconfigured, debated, and reassessed in an ongoing hermeneutic process. Examining science’s historical development reveals a dynamic interplay with the creative impulses of philosophers, scientists, artisans, and technicians. Let us, then, allow *Il Saggiatore* to inspire an inquiry into the creative dimensions inherent in the historical study of science.

17 Ivi, p. 87.

18 See Galileo Galilei, *Il Saggiatore*, cit., xxxi-xxxvii.

3.1 Creating world-visions. The multiple opportunities of narratives. From *Il Saggiatore*

3.1.1 From *Il Saggiatore*

On 6 May 1623, the printing of *Il Saggiatore* began. During the 16th century, several comets (1577, 1585) had marked the night sky. At least two concerns were cogent: what was comets' nature, capable of plowing through the old celestial solid spheres; what was their trajectory, since thanks to Tycho Brahe's methodical practice, astronomers had learned that comet "appearances" could also be "returned". Hypothesizing the supralunar nature of comets and the fluid nature of the sky was the answer to the first question; about the second question, astronomers showed more hesitation and searched for an answer by telescopic practice and a theory of gravitation. Comets' observations were the topic of many correspondences and astronomical treatises from all parts of Europe. The global collection of this information, as well as its sharing, was fundamental to advancing hypotheses. In any case, the old Aristotelian theories were the ubiquitous term of comparison and contrast.

The Aristotelian tradition provided philosophical topics and techniques for arguing about science during the Renaissance. Dialectics was intertwined with rhetoric and became a disquisition, discourse, contrast, and polemic tool. The dialogue form was preferred, and Galileo was the master in the "hot" years of the 17th century. However, the ancient forms of commentary also received new impulses and hybrid forms. *Il Saggiatore*, as the whole Galileo-Grassi polemic, takes place along the lines of the slavish commentary on the opponent's text – or rather, the opponent's scientific community[19]. Grassi published the *Disputatio* in February 1619. The trigger for the controversy occurs with

19 Robert Westfall, *Galileo and Newton: Different Rhetorical Strategies*, in Marcello Pera, William R. Shea (eds.), *Persuading science. The art of scientific rethoric*, Canton-Massachuse, Science History Publications, 1991, pp. 107-124. About Grassi's community, see Ugo Baldini, *Legem impone subactis. Studi su filosofia e scienza dei gesuiti in Italia (1540-1632)*, Roma, Bulzoni, 1992, especially *Appendice* 2.

Galileo's response, the *Discorso delle comete* published under the name of Mario Guiducci. Grassi plays his countermove under the pseudonym of Lotario Sarsi Sigensano to publish the *Libra astronomica*[20], where he adopts a more polemical and harsh tone and explicitly refers to Galileo[21]. Grassi/Sarsi takes advantage of the ambiguity of the term "dittatore"[22] to injure Galileo, the real author of Guiducci's text: who knows if he was more dictator or dictator.

Demonstrations and technical remarks are intimately dialogical, even when they have the guise of a treatise. Words, aphorisms, and jokes have literary and rhetorical value, peppered with references to the classical world to favour consensus and condescension. The scientific language passed from a monologue form to a dialogic one. Moreover, the scientific language was passing, in Galileo's hands, from Latin to italian to express better than in the past the changeability and innovation in the philosophy of nature. Galileo could accord Grassi's text to contemporary standards of eloquence and etiquette, but Galileo ignites and initiates a style of controversy that will be perpetuated[23]. He wrote *Il Saggiatore* in the Tuscan vernacular, and confirmed his habit of including visual language with description and analogies able to bring stars, heavens, and planets down to earth. The title itself reverses the traditional metaphorical meaning of the "scales" with which Cicero weighed the opinions of the vulgar and becomes the instrument for evaluating scholarly opinions with endowment[24]. Among other metaphors, one of the most is the metaphor of the "book of nature". Con-

20 *Libra astronomica ac philosophica*, Perugia, ex Typographia Marci Naccarini, 1619. Besides, in *Edizione nazionale*, vol. VI, pp. 109-180.

21 See also Cesare Marsili to Galileo Galilei, 14 November 1625, Ed. Naz. XIII, pp. 285-6, p. 286.

22 Galileo Galilei, *Il Saggiatore*, in *Edizione nazionale*, p. 114.

23 See Emanuele Zinato, *Il vero in maschera: dialogismi galileiani. Idee e forme nelle prose scientifiche del Seicento*, Bari, Liquori, 2004.

24 Stefania De Toma, *Galileo Galilei, "Il Saggiatore"*, in Pasquale Guaragnella, Stefania De Toma, Pensa Multimedia (eds.), *L'incipit e la tradizione letteraria italiana. Dal Trecento al Cinquecento*, vol. I, Lecce 2011, pp. 37-43.

troversial spirit and irony sprinkled throughout the text: Sarsi/Grassi's most learned witticisms are mocked as[25]

> Trattabile e benigna filosofia, che così piacevolmente e con tanta agevolezza si accommoda alle nostre voglie ed alle nostre necessità!
> [Tractable and benign indeed is such philosophy, so pleasantly and readily adapting itself to men's needs and wishes!]

And even images, like the narrative dimension in general, are pushed to the point of creating fables that give the hint of new epistemic needs. Galileo can invent for his great literary interest, his experience along narrative books and confidence with *humanae litterae*[26].

Galileo argued that the human mind could not uncover nature's secrets without first abandoning the absurd philosophical pursuit of complete knowledge. His contribution to modern science was crucial in this regard: he helped shift the focus from seeking to understand each part of the universe in relation to a grand, all-encompassing framework to a more pragmatic approach aimed to start from how individual parts function before having a unified worldview.

To communicate his new notion of scientific inquiry, Galileo invented a parable, a story about a man who found one day, to his considerable astonishment, that musical sounds were not only produced by birds (the so-called "fable of sounds"). After investigating many sounds, he had the opportunity to catch a cicada and began to study it. By closing its mouth nor stopping its wings, he could not diminish its strident sound, yet he could not see it move its scales or any other parts. In the end, he took his curiosity to the extreme: he opened the

25 Galileo Galilei, *Il Saggiatore*, in *Edizione nazionale*, p. 336. English translation by Drake, *the Assayer*.

26 *Galilaeana Studies in Renaissance and Early Modern Science*, Special Issue XXI, 1, 2024; Massimo Bucciantini (ed.), *Galileo and literature*. Particularly in this issue, Crystal Hall, *Literature in Galileo's library*, pp. 7-34. Viceversa, Galileo's discoveries and book influenced literature and art since very soon (see Crystal Hall, *Galileo, Poetry, and Patronage: Giulio Strozzi's* Venetia edificata *and the Place of Galileo in Seventeenth-Century Italian Poetry*, in «Renaissance Quarterly», 66(4), 2013, pp. 1296-1331).

animal's shell to understand where the sound was coming from and, in doing so, killed it, which he thought were the cause of the sound and he resolved to break them. But everything failed until, driving the needle to date, he transfixed the creature and took its life with its voice so that even then he could not make sure whether the sound had originated in those ligaments. Thus, Galileo wrote[27]:

> onde si ridusse a tanta diffidenza del suo sapere, che domandato come si generavano i suoni, generosamente rispondeva di sapere alcuni modi, ma che teneva per fermo potervene essere cento altri incogniti ed inopinabili.
>
> [His knowledge was reduced to diffidence, so that when asked how sounds were created be used to answer tolerantly that although he knew a few ways, he was sure that many more existed which were not only unknown but unimaginable.]

3.1.2 Narrative statements and history of science: short remarks

Historical accounts rely on narrative sentences to link events in temporal sequence, yet when structured as mere chronicles or reconstructions, they risk an implicit incompleteness by omitting causal explanations. The language of history is further shaped by rhetorical and literary devices, raising key methodological questions: are nomological generalizations in the history of science possible or desirable? Should history explain the past, or must it remain detached from interpretation? The longstanding concerns of theory-ladenness and anachronism highlight the tension between historiographical fragmentation and the unifying impulse of historical explanation.

Uebel observes: "Narrative histories should be aggregative, insofar as they are histories, but cannot be, insofar as they are narrative."[28] As a

27 Galileo Galilei, *Il Saggiatore*, in *Edizione nazionale*, cit., vol. 6, p. 281. English translation by Drake, *The Assayer*.

28 Thomas Uebel, *Philosophy of History and History of Philosophy of Science*, in *Hopos: The Journal of the International Society for the History of Philosophy of Science*, vol. 7, Issue 1,

result, every grand narrative – or "mega-narrative" – has been dismantled[29]. He continues to examine how a certain degree of "presentism" can not only be maintained but may also become essential[30]. In Uebel's opinion, Danto[31]'s insights clarify how narrative standards shape historical practice. If we apply them in light of a "narrative" approach after the historical turn in the historiography of science, we focus on at least two points. First, the necessity of narrative statements, since even if non-narrative history exists, we can trace connections among events when we explore the origins and development of a scientific concept. Second, temporal asymmetry and conceptual asymmetry in narrative sentences because the description or understanding of an event often includes knowledge or relies on concepts not coeval at such an event.

As history remains open to reinterpretation, it must balance retroactive understanding with the risk of anachronism and ensure historiographical validity by debates within an entire scholarly community. The historian of science engages in three key activities:

1. Synoptic analysis, constructing a comprehensive yet contingent perspective on historical problems.
2. Feedback revision, reassessing past accounts through critical reinterpretation.
3. Validation, refining narratives according to audience and context.

Through this approach, the history of science effectively communicates complex ideas, blending narrative methods with cultural, bio-

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2017, pp. 1-30. See also David Webermann, *The Nonfixity of the Historical Past*, in «Review of Metaphysics», 1997, 50, pp. 49-68.

29 Jo Guldi, David Armitage, *The History Manifesto*, Cambridge, Cambridge University Press, 2014 (online publication 2017: The History Manifesto); Antonella Romano, *The History Manifesto, History of Science, and Big Narratives: Some Pending Questions*, in «Isis», volume CVII, 2, June 2016, pp. 338-340.

30 Uebel, *Philosophy of History and History of Philosophy of Science*, cit.

31 Arthur Danto, *Narrative Sentences*, in «History and Theory», 2, no. 2, 1962, pp. 146-179, https://doi.org/10.2307/2504460; Id., *Analytical Philosophy of History*, Cambridge, Cambridge University Press, 1965.

graphical, and sociopolitical elements to enhance accessibility without sacrificing accuracy.

The power of the history of science to shape worldviews lies in its capacity to relativize and problematize. The history of science demonstrates how the questions posed by science have evolved, offering significant philosophical insights. Notably, the canon of "thinkers" traditionally regarded as philosophers may not always align with those addressing the same questions[32]. Galileo's challenge to the principle of authority can be extended to all past views, mainly when authority is defined as the categories conforming to a dominant perspective. However, this does not lead to a rejection of theoretical interpretation. On the contrary, the historiographical approach enriches the range of explanatory possibilities, making them more complex and less dogmatic. It achieves this without lapsing into fiction, grounding itself in rigorous engagement with sources, philological and technical analysis, and logical and speculative inquiry. For these reasons, one should talk in terms of storythinking and not just storytelling[33].

3.2 Material creations and Material History of Science

3.2.1 From Il Saggiatore

Four instruments immediately catch the eye in the frontispiece of *The Assayer*[34], engraved by Francesco Villamena: an astrolabe held by the feminine allegory of Natural Philosophy, an armillary sphere and a compass in the hands of the allegory of Mathematics, and, on the stylobate beneath her feet, two telescopes crossed around the *occhialino* – a magnifying glass used to observe and reproduce details of plants

32 Uebel, *Philosophy of History and History of Philosophy of Science*, p. 4.

33 Angus Fletcher, *Storythinking: The New Science of Narrative Intelligence*, Columbia University Press, 2023.

34 Pietro Redondi, *Teologia ed epistemologia nella rivoluzione scientifica*, in «Belfagor», xlv, 1 Jan 1990, pp. 613-636.

and animals, particularly bees. Surprisingly, the instrument one might most expect to find—the precision balance, or "saggiatore" in italian[35], as the balance is depicted in the title page of Grassi/Sarsi's *Libra astronomica ac philosophica* – is absent. A precision balance was part of an initial draft for the frontispiece, but Villamena's design was ultimately preferred[36]. It is unlikely that the telescope was chosen simply because it was already widely known. While it's true that, following Galileo's publication of *Sidereus Nuncius* in 1610, the telescope had achieved almost mythical status, the ongoing controversy between Grassi and Galileo consistently leaned on the metaphor of the scales. Even after *Il Saggiatore* was published, Grassi maintained this metaphor in his subsequent response, *Ratio ponderum librae et symballae* (1626), although the debate had largely subsided by then. Nevertheless, the telescope played a pivotal role in the sequence of arguments.

The comets of 1618 were the first to be observed with a telescope. In 1619, the Jesuit Orazio Grassi published his *Disputatio Astronomica*, arguing that comets are celestial bodies located above the Moon's orbit. Grassi noted the lack of observable parallax of the comet, and this argument was crucial. He added also further considerations, as calculations of comet's distance and speed, based on the principle that celestial bodies move faster or slower depending on their proximity. He also considered the comet's apparent size, and its disappearance near the Arctic due to vapors on the horizon. Besides, Grassi observed that the telescope did not produce any significant magnification (*incrementum*) of the cometary body, unlike the Moon, which undergoes noticeable magnification through the same instrument. Since the telescope magnifies less as the distance of the object increases – which was a wrong principle – Grassi concluded that the comet must be farther away than the Moon and placed the comet between the Moon and the Sun. Galileo

35 Marco Bianchi, *Il dire galileiano per titoli. Una nota lessicale su* "Il Saggiatore", in «Zeitschrift für romanische Philologie», cxxx, 3, 2014, pp. 802-814.

36 Galileo Galilei to Francesco Stelluti, Rome, September 8th 1623, in *Edizione nazionale*, xiii, p. 129.

read in it an allusion to his personal knowledge in optics[37], while his fame was rapidly growing[38].

Grassi further discussed the limitations of small instruments, asserting that their data might be unreliable compared to the more precise measurements obtained by Tycho Brahe's superior instruments. Relying on information received from Cologne, Grassi confirmed his conclusion that the comet was above the Moon. He positioned himself as an innovator by rejecting Aristotelian theories, which held that comets were atmospheric phenomena below the Moon. Another noteworthy element in Grassi's analysis was his use of projections of the comet's position on a plane tangent to the celestial sphere. The result showed a straight line, suggesting that the comet's circular path had such a large radius that it could only lie above the lunar sky. This conclusion was beautifully illustrated in the magnificent diagram included in the *Disputatio*[39].

Galileo replied with Marco Guiducci's pen in the *Discorso delle comete*[40], showing his consternation at such terse arguments and insisting on what were the consequences of the lack of parallaxes in Grassi. Therefore, the author expanded extensively with examples and reasoning on the use of the telescope. How can it be said, Galileo/Guiducci warned sarcastically, that distant things would not be magnified, when previously unseen fixed stars have appeared in the telescope? Showing up from nothing to the visible is, on the contrary, infinite magnification![41] Similarly, Galileo/ Guiducci insists on the differences caused

37 On the suspicion about Galileo's optical skills, see Giorgio Abetti, *Amici e nemici di Galileo*, Milano, Bompiani, 1945, p. 118; Mario Livio, *Galileo. Contro i nemici del pensiero scientifico*, 2021, pp. 189-196.

38 Hall, *Literature in Galileo's library*, (see footnote 24).

39 See Besomi-Helbing, *Annotazioni alla* De tribus cometis disputatio, in Galileo Galilei, Mario Guiduccio, *Discorso delle comete,* Roma-Padova, Editrice Antenore, 2002. See also *Disputatio* in *Edizione nazionale*, vol. vi, intra pp. 32 and 33.

40 Galileo Galilei, *Discorso delle comete di Mario Guiducci fatto da lui nell'Accademia fiorentina nel suo medesimo consolato*, nella Stamperia di Pietro Cecconcelli, Firenze, 1619. See also in *Edizione nazionale*, vol. vi, pp. 37-108.

41 Galilei Galilei, *Discorso*, in *Edizione nazionale*, p. 75.

by the variations of the exemplars of the instruments, such as by the length of eyepiece tubes. Again, the telescope shows objects in a definite way without glaring at their outline. Grassi's arguments, in short, were completely equivocal. On the contrary, an astronomer must not forget his perception and what depends on the observer: "Ora, se tale irradiazione è nell'occhio nostro, com'è manifesto, che merauiglia è se 'l Telescopio non l'aggrandisce?"[42]. Therefore, any argument based on telescope magnifications is to be rejected.

Armed with the pseudonym Lothario Sarsi, Grassi responds with the *Libra astronomica ac philosophica*[43] in kind by letting the telescope be described as an instrument of observation and not speculation. In fact, among visible things, nobody should discuss the transition from Nothing to Something, because the telescope does not observe anything that does not yet exist[44]. Grassi/Sarsi wants to be magnanimous and allows Galileo to refer to what is not yet seen as a Nothing, almost waiting for an act of divine creation to bring it into existence. Even granting this, Galileo is wrong: in fact, elsewhere he claims that the telescope does not produce infinite magnifications but according to precise proportions!

Galileo's response in *Il Saggiatore* repeated the arguments offered in *Discorso sulle comete* but in the form of a slavish commentary on the *Libra* and reinforcing references to optics and geometry[45]. Sometimes, he went also back to the *Disputatio*, as in the case of the question of the parallaxes measured between Rome and Antwerp: Sarsi would like the comet have had parallaxes major than the solar one, but his master Grassi calculated a degree of around 56° 56'[46], but Galileo disputes ex-

42 Ivi, p. 85. [English translation: "Now, if this radiation is in our eyes, as is evident, what wonder is it that the telescope magnifies it?"].

43 Orazio Grassi, *Libra astronomica ac philosophica*, Perugia, ex Typographia Marci Naccarini, 1619.

44 Id., *Libra*, in *Edizione nazionale*, p. 122.

45 Michele Camerota, Franco Giudice, *Introduzione*, in Galileo Galileo, *Il Saggiatore*, pp. xxx.

46 Ivi, pp. 159-160, in particular footnote 575.

actly this calculation, arguing that any object observed from that terrestrial distance could confer an angle greater than 50°. Sarsi replied again in the *Ratio* (*examen xxvi*[47]) and affirmed again that the comet is not a sort of effect from the solar light. But the polemic was going to fade away around the comets. Indeed, the most significant divergences concerned the trajectory of comets and the parallaxes, in line to reject the true purpose of Grassi's theses, which is the true aim of the polemic by Galileo: the defense of the immobility of the Earth and Tycho's system[48]. Yet, tension and disagreement emerge again over the use of the instrument. "Mai non si è detto, l'accrescimento nelle stelle fisse esser infinito"[49], says Galileo Galileo about the mentioned question of the magnification from nothing to something. Galileo replies against Sarsi/Grassi as pedantic (*cavilloso*). Unable to accommodate Grassi/Sarsi's unpleasant criticism, Galileo carries out a verbose examination on his opponent's argument. He defends the greatness of the telescope by extolling its two capabilities: enlarging objects by widening the angle under which they can be observed and focusing objects by dissolving halos and lights that disturb their real perception.

3.2.2 Instruments, objects and material creations: short remarks

Galileo and Grassi's optical telescopes operated within the same frequency range as the human eye, with their primary distinction lying in the magnification they provided – effectively extending and enhancing human perception. By contrast, a radio telescope enables the detection of aspects of reality that are entirely imperceptible to the unaided human eye, revealing them only through instrumental mediation. Numerous other devices similarly grant access to physical phenomena

47 Orazio Grassi, *Libra*, in *Edizione nazionale*, pp. 114-115.

48 Michele Camerota, Franco Giudice, *Introduzione*, in Galileo Galileo, *Il Saggiatore*, pp. xxxi ff.

49 Galileo Galilei, *Il Saggiatore*, p. 245. [English translation: "It has never been said that the growth of fixed stars is infinite".]

beyond direct human perception. A straightforward example is the magnetic compass, which detects Earth's magnetic field – an element of reality that remains imperceptible to our senses[50].

In *Il Saggiatore*, Galileo extensively discusses the relationship between sensory perception and reality. The distinction between data accessible directly through the senses and those requiring instrumental mediation presents a philosophical challenge that Galileo, among others, had to navigate. With the telescope, Galileo not only discovered Jupiter's satellites but also magnified their significance in *Sidereus Nuncius*. This work elevated him from an obscure mathematics teacher to a court mathematician. Later, in *Il Saggiatore*, he employed the same instrument to dissolve the solidity of comets into mere optical phenomena, thereby enshrining the practice of doubt as a cornerstone of scientific inquiry[51].

Establishing an instrument as a credible observer of reality – or, more precisely, as a means of investigating specific aspects of reality – is an epistemological issue that has broader implications for the role of instruments in scientific knowledge. Within the context of the Galilean revolution, this issue was of fundamental importance, as using the telescope required a range of methodological and interpretative strategies. These included the technical skill to operate and refine the instrument and the ability to interpret its data and determine its epistemic significance in adjudicating between competing models of the world. Notably, Grassi incorporated telescopic observations – albeit inaccurately – into his arguments rather than relying solely on unaided visual perception. Galileo engaged in discussions regarding the limitations and challenges of telescopic observation with Christopher Clavius, the leading Jesuit mathematician of his time[52]. The Jes-

50 Harold I. Brown, *Galileo on the Telescope and the Eye*, in «Journal of the History of Ideas», xlvi, 4, 1985 (Oct.-Dec.), pp. 487-501.

51 Giovanni Baffetti, *Il Metodo e l'errore. Galileo e La Filologia Del Libro Della Natura*, in «Lettere Italiane» 69/3 (2017), pp. 499–512.

52 Galileo Galilei a Cristoforo Clavio in Roma, 17 September 1610, in *Edizione nazionale*, vol. x, vol. 431-432.

uits' engagement with instrumental investigations and their cosmological implications had two significant consequences. First, it did not impede the transition from observational to instrumental astronomy. Second, it led to paradoxical situations in which telescopic data were employed to support advanced forms of geoheliocentrism[53].

The telescope, its construction, the expertise required to refine it, and its ability to generate new data and insights into nature became a mark of credibility. The trust one astronomer placed in another increasingly depended on demonstrating proficiency in using this instrument. This principle extends more broadly to science as a whole, as exemplified in Galileo's case and modern scientific practice. Scientific instruments were not only tools of inquiry but also artifacts, works of craftsmanship, and commercial products – objects that circulated within diverse contexts and served multiple purposes[54].

Scientific objects are the entities, processes, and phenomena individuated, represented, investigated and used as tools in scientific practice. They have beginnings in time, when boundaries are carved around them; they are endowed with properties, which enable them to perform their epistemic functions; they have blind spots, for which they become subject to theorizing and experimental investigation; they are often laden with values and emotional significance; and they sometimes pass away, for a multitude of reasons. Because of these characteristics, they lend themselves to biographical narratives[55].

53 Flavia Marcacci, *Cieli in contraddizione. Giovanni Battista Riccioli e il terzo sistema del mondo*, Modena-Perugia, Accademia Nazionale di Scienze Lettere e Arti di Modena-Aguaplano L'Officina del Libro, 2018; Id., *G.B. Riccioli's Geo-heliocentric Use of Epicepicycles, Ellipses and Spirals*, in «Journal for the History of Astronomy», May 2023, 1-22; Flavia Marcacci, Paolo Bussotti, *How to use Kepler's first and second laws in a geo-heliocentric system? Ask GB. Riccioli*, in «Archive for the History of exact sciences», 79, 4 (2025), https://doi.org/10.1007/s00407-024-00343-3.

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

55 Theodore Arabatzis, *Do scientific objects have a life (which may end)?*, in «Science in Context», 2021, 34, pp. 195-208. See also Id., *Representing Electrons: A Biographical Approach to Theoretical Entities*, Chicago, University of Chicago Press, 2006; Lorraine Daston, *Biographies of Scientific Objects*, Chicago, University of Chicago

Beyond specific methodological approaches, it is essential to acknowledge the materiality of the objects at the core of scientific inquiry. This consideration extends beyond scientific instruments to encompass a broader range of objects, including works of art, architectural structures, museum exhibits, and various artifacts that contribute to the historical development of science. These material entities possess both ontological and epistemic dimensions, a recognition that extends even to purely theoretical domains [56]. Moreover, they play a fundamental role in preserving and valorizing scientific and technological heritage[57]. Scientific instruments and naturalistic collections are irreplaceable three-dimensional sources for the material history of science[58]. They, further, are the legacy of the culture of entire social groups, with their theoretical and practical expressions[59].

3.3 Creating styles of reasonings. History of Science, logic, argumentation

3.3.1 From *Il Saggiatore*

Versed in Aristotelian logic, Grassi was fond of casting his results in syllogistic form. Galileo mocked him for attempting to solve with logical arguments problems that could only be settled by empirical evi-

Press, 2000; Hans-Jörg Rheinberger, *Toward a History of Epistemic Things: Synthesizing Proteins in the Test Tube*, Stanford, Stanford University Press, 1997.

56 Barry Smith, *Beyond concepts: Ontology as Reality Representation*, in Achille Varzi, Laure Vieu (eds.), *Proceedings of FOIS 2004. International Conference on Formal Ontology and Information Systems*, Turin, 4-6 November 2004, pp. 73-84.

57 In Italy the "Scientific and technological heritage" received specific regulation in the Urbani Code only in 2004. For a recent proposal to valorize the Italian heritage, see Elena Canadelli, Paola Bernardette di Lieto, *Da cimeli a beni culturali: fonti per una storia del patrimonio scientifico italiano,* Editrice bibliografica, 2024.

58 Marco Beretta, *Storia materiale della scienza*, nuova edizione, Roma, Carocci, 2024.

59 Barbara Kirshenblatt-Gimblett, *Intangible heritage as metacultural production*, in «Museum international», 56, 2018, pp. 52-65.

dence. Galileo speaks of "natural logic" for this, meaning logical reasoning based on experience: Sarsi/Grassi defends the idea that there are bodies that produce heat without losing weight since in his experiments, he was unable to verify any change in weight in an overheated copper body[60]. Moreover, if not even the best balance can register this alteration, on what principle do we continue to insist? Galileo answers by classifying three types of contact between bodies: those that rub together but are very smooth and produce no heat (polished mirrors), those that rub together heat up and wear out (such as filed iron), and those that remain doubtful. In the latter case, seeing that the heat is there for sure, one concludes that they lose weight! Galileo relies on analogical reasoning designed to cover up the weakness of experimental detection. Moreover, he accuses Sarsi as superficial as a philosopher. But Galileo does not skimp on nods to logical figures: thus, he denounces the *ad hominem* fallacies of his opponent[61], blames his opponent's vice of drawing false conclusions from true premises[62].

Ma mi duol bene oltre modo, che l'essere esse vere, gli è di maggior pregiudicio, che se fusser false; poiche la principal conclusione; che per esse doueua essere dimostrata, è falsissima, ne credo, che ci sia verso di poter sostenere, che grauemente non pecchi in Logica quegli, che dà proposizioni vere deduce una conclusion falsa. [...]

Chiarissima è adunque la falsità della conchiusione. Resta ora che mostriamo la fallacia nel dedurla da premesse vere. E quì mi pare, che al Sarsi sia accaduto quello, che accaderebbe ad un mercante, che nel riueder sopra i suoi libri, lo stato suo, leggesse solamente le facce dell'auere, e che così si persuadesse di star bene, ed esser ricco; la qual conchiusione sarebbe vera, quando all'incontro non vi fussero le facce del dare.

[But it occurs to me, beyond all measure, that the fact of their being true brings him greater harm than if they were false; for the principal conclusion, which ought to have been demonstrated on their basis, is utterly false. Nor do

60 Galileo Galilei, *Il saggiatore*, in *Edizione nazionale*, cit., vol. vi, pp. 332-335.

61 Ivi, p. 319.

62 Ivi, p. 254 and p. 255.

I believe there is any way to defend him from the grave error in logic he commits, as he derives a false conclusion from true premises. [...]

Thus, the falsity of the conclusion is manifest. What remains is to expose the fallacy in deducing it from true premises. And here, it seems to me, Sarsi has fallen into the very error that would befall a merchant who, in reviewing his accounts, considered only his revenues and thus convinced himself that he was prosperous and wealthy – his conclusion would indeed be true, but only if there were no expenses to account for].

Galileo, however, is honest: Grassi/Sarsi observes and considers experiences and tries to reproduce and examine them. His gaze, however, is deceived: those experiences must be interpreted correctly, so that Grassi "aurebbe scoperta la fallacia del suo sillogismo" ("would have discovered the fallacy of his syllogism"[63]).

A new special philosophical issue looms. Facts do not speak unless interrogated, and questions asked limits and determines the range of meaningful answers. Both Galileo and Grassi called upon experimental facts to justify certain features of their own theories but they never suggested that experiments give rise to theories. What they assumed was that experiments illustrated, confirmed, or falsified existing hypotheses. The laboratory was not the breeding-ground for them but the testing-place of theories. We can see this in their debates over the influence of revolving spheres, brilliantly explained by Shea in a long passage but valuable to be read[64]:

Aristotle claimed that the vapors rising from the Earth were carried around by the motion of the sky. Galileo-Guiducci[65] denied that a light material such as air could be swept along simply by touching the surface of its container, and he proved this experimentally by placing a lighted candle in the center of a hollow vessel and showing that when the vessel revolves the flame remains erect and, therefore, that the air is at rest. Grassi retorted with

63 Ivi, p. 300: [would have discovered the fallacy of his syllogism].

64 William R. Shea, *Galileo's intellectual revolution*, pp. 92-93.

65 *Discorso delle comete di Mario Guiducci*, ch. 11.

a modified experiment. He moved the candle from the center and placed it close to the internal surface of the vessel, triumphantly noting that the flame was deflected in the direction in which the vessel was twirling. A strip of paper hanging from a thread and suspended near the surface of the vessel was even more deflected, thus confirming that the air moved with its container. Galileo accepted the experimental challenge in *The Assayer*[66]. This time he took two lighted candles, attached one inside the vessel about two centimeters from the top, and held the other in his hand inside the vessel at the same height. The vessel was then set in motion. He reasoned that if the motion was imparted to the air as Grassi claimed, the flame of the candle attached to the vessel would not bend because it would move with the same speed as the air, whereas the flame of the candle that was not attached to the vessel would be deflected. Experiment, however, prove just the opposite: the flame of the candle held in the hand remained straight while the flame of the candle fastened to the rotating vessel was deflected. Galileo concluded that the most Grassi could claim for his experiment was that a very thin layer of air was carried around by the roughness of the surface of the vessel. In his rejoinder, Grassi argued that he had never asserted that the air rotated as swiftly as the sphere in which it was contained, and that Galileo was experiment was a distortion of the real empirical situation in which the flame of the candle fastened to the vessel met with resistance from the air, not because the air did not move but because it did not move as swiftly as the vessel itself. By shifting his ground, Grassi managed, therefore, to render Galileo's experiment innocuous.

3.3.2 Philosophical and historical reciprocity: short remarks

Is the history of science truly irrelevant to philosophy, as Norwood Russell Hanson claimed in 1962?[67] Thomas Kuhn observed that philosophers of science historically relied on the history of science to inform their philosophical inquiries[68]. However, he lamented how infrequently the

66 Galileo Galilei, *Il Saggiatore*, ch. 40.

67 Norwood R. Hanson, *The irrelevance of history of science to philosophy of sciences*.

68 Thomas Kuhn, *The Relations between the History and the Philosophy of Science*, in Id., *The Essential Tension: Selected Studies in Scientific Tradition and Change*, 3-20. Chicago, IL: University of Chicago Press.

reverse occurred. In recent years, this dynamic has shifted. There has been a surge of interest in historical epistemology and related approaches, accompanied by a growing recognition that historiographical work can benefit from deeper epistemic awareness. By considering questions such as the nature of scientific rationality, the role of epistemic virtues in scientific research, and the motivations behind fierce theoretical competition, historians can identify particularly fruitful areas of inquiry. This enables them to craft rich historical interpretations of scientific theoretical activity. Conversely, philosophical theorization of scientific inquiry offers significant insights that can enhance and stimulate historiographical practices[69]. Thus, one can show the birth of a concept when there was not yet the vocabulary to talk about it, and, at the same time, provide good justifications in involving contemporary concept reading the past[70].

> Historical accounts of past scientific practice involve metascientific concepts (e.g. 'discovery' or 'experiment'), which are not philosophically innocent and require philosophical scrutiny [...]. I will suggest that philosophical reflection on these concepts can be historiographically fecund: it can elucidate historiographical categories, justify historiographical choices and, thereby, enrich and improve the stories that historians tell about past science as a knowledge-producing enterprise[71].

69 William R. Shea, *The Quest for Scientific Rationality: Some Historical Considerations*, in Marcello Pera, Joseph C. Pitt (eds.), *Rational Changes in Science: Essays on Scientific Reasoning*, Dordrecht-Boston-Lankaster-Tokyo, D. Reidel Publishing Company, 1987, pp. 155-176. See also Flavia Marcacci, *Scientific Change, Realism, and History of Science*, in Adriano Angelucci, Vincenzo Fano, Pierluigi Graziani, Giovanni Galli, Gino Tarozzi (eds.), *Scientific Change, Realism, and History of Science. Festschrift for Mario Alai*, Milano, Franco Angeli, 2023, pp. 61-71.

70 In this perspective, as an example: Domenique Lambert, *The "Primeval Atom Hypothesis": Where Did It Come From? What Is Its Status?*, and Flavia Marcacci, Gino Tarozzi, *Max Planck, Causality, and the Necessity of God*, in Paul Allen, Flavia Marcacci (eds.), *Divined explanation. The Theological and Philosophical Context for the Development of the Sciences (1600-2000)*, Leiden-Boston, Brill, 2024 respectively at pp. 189-209 and pp. 210-231.

71 Theodore Arabatzis, *What's in It for the Historian of Science? Reflections on the Value of Philosophy of Science for History of Science*, in «International Studies in the Philosophy of Science», 31, 1, 2017, pp. 69-82: 70.

The interaction, included the use of such metascientific concepts, must not have the pretense for a total explanation of what happened in past science. Such pretense does not respect the actual aim of an historian. Anyway, the intention can be absolved:

> a philosophical perspective, if worth its mettle, should assist the historians to write better history, [...] more plausible, and more coherent stories about the past scientific practice. [...] Insights from history of science can be (and, indeed, have been) brought to bear on and enrich the historiography of science.

Il Saggiatore suggests many examples about the possibility of interaction between historical analysis and recent philosophical and logical accounts. Let take into consideration the contemporary issue of underdetermination and competing theories: no theory wins at the end. There is no agreement or dominant theory at the end of the dispute. Conversely, the theory choice is based on a dialogical conflict and a controversial style where each part furnishes his point of view about the nature of the comets. The same data are interpreted in opposite ways by Grassi and Galileo. Some general criteria overlap (for instance, the importance of observations), but sometimes, they oppose (for instance, about the role of authority). A definitive solution lacks and exactly for that, for not having a conclusive cometary theory, Galileo is free on the one hand to propose the fable of sounds in a perfect literary style, on the other hand, he proposes the idea of the progressive and never-ending scientific process of knowledge and the skeptical ground of science.

There are at least other two examples. *Il Saggiatore*, and not only the other Galileo's works, suggests material for the topic of scientific and conceptual change[72]. The tensions between the two opposite perspec-

72 Joseph P. Pitt, *Galileo and rationality: the case of the tides*, in Marcello Pera, Joseph Pitt (eds.), *Rational Changes in Science*, pp. 135-153; Jean-Claude Pont, *Épistémologie et Méthodologie Dans l'œuvre de Galilée*, in «Anabases», no. 15 (2012), pp. 163-82. About the scientific change and history of science, in particular: Michael Friedman, *Dy-*

tives is not only "essential": it is omnipresent, deflagrating, and devastating. That tension becomes like a tension between "styles of reasoning"[73]: both empirical but dogmatic and deductive for Grassi, skeptical and inductive for Galileo. Besides, *Il Saggiatore* suggests the style of recent "dialogical" logical approaches[74], base not on axiomatic deduction but on the development of demonstrations that one party bases solely on the other party's response. Although not formally and except for the beginning step of the *Disputatio*, the demonstrations exhibited by Grassi and Galileo along the seesaw of mutual backlash are drawn from what the opponent advances. Each of these topics deserves careful study of the text and specific analysis that cannot be done here.

History, science and philosophy can stimulate each other without losing autonomy. The three perspectives can interact with a view to compound reciprocity and integration, as Galileo wanted, when he cited Ariosto and the gentle contention, he liked so much[75]:

> Tra noi per gentilezza si contenda.
> [Let us compete in courtesy among ourselves.]

Even if one can suspect that Galileo repeated Ariosto out of flattery!

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namics of Reason. The 1999 Kant lectures at Stanford University, Stanford, CSLI Publications, 2001 and David Marshall Miller, *Friedman, Galileo, and Reciprocal Iteration*, in «Philosophy of Science» 78, no. 5 (2011), pp. 1293-1305.

73 Ian Hacking, *'Style' for Historians and Philosophers*, in «Studies in History and Philosophy of Science», 1992, 23 (1):1-20 [= Ian Hacking, *Historical Ontology*, Harvard University Press, Cambridge-Massachussets 2002, 178-199].

74 Nicolas Clerbout, Zoe McConaughey, *Dialogical Logic*, in «The Stanford Encyclopedia of Philosophy» (Fall 2022 Edition), Edward N. Zalta, Uri Nodelman (eds.), = https://plato.stanford.edu/archives/fall2022/entries/logic-dialogical/; Shahid Rahman, Flavia Marcacci, *Dialogical Logic*, 2023, ffhalshs-04144147f (Italian translation forthcoming in «Aphex. Rivista Italiana di Filosofia analitica»).

75 Ludovico Ariosto in Galileo Galilei, *Il* Saggiatore, in *Edizione nazionale*, p. 317.

4. Conclusion: historians of science, creators

The framework outlined here highlights the relationship between history, philosophy, and science as dynamic, intricate, and, at times, contentious, searching for order challenging. This interaction fosters a heuristic approach that can guide both historians and philosophers in their engagement with science. From this perspective, we can identify three key creative moments in the historian's activity:

- *The creation of world-visions.* The narrative dimension of history, in dialectical relation with historiographical explanation, continually generates new syntheses in an ongoing process of understanding the past. The history of science serves to break free from biases and authoritarian epistemic principles, yet it does so through rigorous rational effort.
- *The creation of material operations*. Understanding history requires moving beyond rigid disciplinary boundaries. Material culture embodies the three-dimensional expression of abstract concepts. Behind objects lie invisible yet equally significant actors – that is, concepts – in the history of science.
- *The creation of logical-epistemic frameworks*. History of science investigates the development of ways of argumentation and styles of reasoning. It reveals the interactions among disciplines while simultaneously being shaped by the very disciplines it influences.

Historical inquiry reminds us that no account is ever definitive and that science itself remains an open system, constantly interacting with both practical and theoretical domains. From a philosophical standpoint, at least a few fundamental principles emerge to support historical awareness. First, periodization, though central to historical practice, must contend with the vast and intricate nature of scientific development, where concepts, methodologies, and external influences are deeply interwoven. Second, history encompasses both observable and unobservable actors, including individuals and communities, as well as humans and concepts. Third, analyzing science historically demands multilevel reasoning: since science evolves over time, its practitioners, experiments, and theories transform in tandem with broader shifts in epistemic frameworks and modes of demonstration characteristic of each era. Finally, historical explanations remain partial and contingent, shaped by the myriad factors at play – including the historian's own perspective.

This approach rejects both dogmatism and relativism, embracing exceptions not as anomalies but as sources of insight. Historians resist the Procrustean bed of homogenization, favoring creativity and acknowledging evolution. Consequently, historical analysis offers a multilayered account of the past grounded in a deep philosophical perspective. The quality of historical interpretation reflects the richness of the elements engaged and the depth of their interaction. A nuanced understanding of the past is essential for comprehending the present and shaping future inquiries.

Yet, interaction does not imply mere overlap or duplication. Authentic engagement occurs only between distinct elements. Someone[76] cautioned against expecting philosophy to become science or stripping science of its unique interpretative methods. The same applies to history, which must resist rigid certainties, thrives on critical questioning, and seeks to grasp the evolution of ideas. In the diverse landscape of historical inquiry, historians are the observers who recognize nascent ideas, allowing them to flourish. In this way, critical thinking and the growth of knowledge are mutually reinforcing. And Galileo's *Il Saggiatore* still shows its depth.

Riassunto In questo saggio si intende leggere *Il Saggiatore* di Galileo Galilei come esemplare punto di incontro fra storia della scienza, storia della filosofia e filosofia della scienza. Attraverso il confronto con Orazio Grassi e la tradizione gesuitica che difendeva il sistema astronomico di Tycho Brahe, Galileo trasforma la controversia sulle comete in un laboratorio epistemologico dove si intrecciano esperienza, linguaggio e narrazione. Vengono messe in evidenza tre dimensioni creative proprie dello storico della scienza:

76 Michael Friedman, *Dynamics of reason*, pp. 15-24.

la creazione di visioni del mondo mediante la narrazione; la creazione materiale, legata allo studio di strumenti scientifici; e la creazione logico-epistemica, che investiga gli stili di ragionamento e le forme di argomentazione e di dialogo. L'approccio interdisciplinare proposto intreccia storiografia, filosofia e analisi dei testi scientifici, suggerendo che la storia della scienza non è solo descrizione del passato, ma anche soprattutto un esercizio critico di interpretazione. Essa offre in questo modo elementi di elaborazione per categorie filosofiche utili a comprendere la scienza. *Il Saggiatore* diventa così un paradigma per comprendere la tensione tra esperienza e teoria, tra autorità e creatività, e per valorizzare la funzione del racconto nella costruzione della razionalità scientifica.

Abstract This essay reads Galileo Galilei's *Il Saggiatore* as an exemplary meeting point between the history of science, the history of philosophy, and the philosophy of science. Through his confrontation with Orazio Grassi and the Jesuit tradition that defended Tycho Brahe's astronomical system, Galileo transforms the controversy over comets into an epistemological laboratory where experience, language, and narrative intertwine. The essay highlights three creative dimensions characteristic of the historian of science's work: the creation of worldviews through narrative; a reflection about the material creation associated with scientific instruments and objects; and the logical-epistemic creation, which investigates styles of reasoning and forms of argumentation and dialogue. The proposed interdisciplinary approach weaves together historiography, philosophy, and the analysis of scientific texts, suggesting that the history of science is not merely a description of the past but above all a critical exercise in interpretation. In doing so, it provides conceptual tools for developing philosophical categories useful for understanding science. *Il Saggiatore* thus emerges as a paradigm for grasping the tension between experience and theory, between authority and creativity, and for recognizing the role of narrative in the construction of scientific rationality.