Science in Context (2025), 1–37
doi:10.1017/S0269889725100653

CAMBRIDGE UNIVERSITY PRESS

RESEARCH ARTICLE

Computational Rifts: Parsing the Context of Early Modern Natural Philosophy

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Argument
Ongoing debates among historians of early modern philosophy are concerned with how to best understand the context of historical works and authors. Current methods usually rely on qualitative assessments made by the historians themselves and do not define constraints that can be used to profile a given context in more quantitative terms. In this paper, we present a computational method that can be used to parse a large corpus of works based on their linguistic features, alongside some preliminary information that can be retrieved from the associated metadata. The goal of the method is to use the available information about the corpus to create broad groups that can work as sub-contexts for better understanding different sorts of works and authors. In turn, this makes it possible to better profile each group and identify its most distinguishing linguistic features. Once these features are clarified, it will eventually become possible to also identify what the most representative works and authors in each group are and which of them may be worth exploring in greater detail. This classification method thus allows historians to integrate their qualitative assessments with quantitative studies in order to better define the relevant context for any given work.

Keywords: early modern philosophy; contextualism; natural language processing; network analysis; computational history of philosophy

C'è lì un posto, lo ha lasciato tuo padre.
Non dovrai che restare sul ponte
e guardare le altre navi passare
le più piccole dirigile al fiume
le più grandi sanno già dove andare.

Fabrizio De André, *La canzone del padre*

1. Introduction

Philosophical and scientific ideas can manifest and be instantiated in multifarious forms, from individual intuitions to social practices. A core approach to investigating the evolution and unfolding of these ideas, at least during the early modern period, is also to look at how they manifest themselves through language and, more specifically, in written discourse. It is almost a reflex for a historian wishing to learn about what Newton *thought* to go and read what Newton *wrote*. As we enter the arena of discourse analysis, and particularly that of written discourse analysis, it becomes apparent that discourse looks more like a dense polyphonic structure than a

sequence of otherwise disconnected solo performances. Any linguistic articulation is inevitably part of a conversation, a dialogue, which is open on all fronts to a potentially infinite number of interlocutors. Reading Newton *only* does not yield a complete picture of his thought. One would also need to understand *why* he was thinking what he was thinking (and writing), which sort of problems were more urgent for him, and which ones might have been more remote, if not entirely inconceivable.

To deepen such an investigation, the natural move is to read more texts, possibly somehow connected in relevant ways with Newton's work, so as to better understand the *context* of Newton's ideas. This is a fairly intuitive and commonsensical understanding of what a context is. Sometimes, the notion of context can be taken in a much broader sense—to include anything that was happening around (and arguably somehow influencing) the author or work that is the focal point of one's research. In a narrower sense, though, as we look at the ways in which ideas are embodied by texts, the context we look for is a certain set of other texts that can be more or less relevantly connected with the main source (both the criteria for relevance and their weight can be the object of further discussions). By taking this broader contextualist view, we can see, for instance, which kinds of ideas were more widespread and thus less unique to a single author, which were instead more idiosyncratically dispersed through the context, or, taking time into account, how these distributions and relations evolved during a given period of time.

However, as rewarding as this contextualist investigation may promise to be, it is not obvious that historians of early modern philosophy and science are willing to wholeheartedly embark on it. Reconstructing the context of any source might become an endless task, given the potentially indefinite scope of the context itself, which can always be expanded by taking into account further relations and more remote sources. This may be just one of the many pragmatic reasons why, especially in the Anglophone scholarship since the second world war (see discussion in Beiser 2016), a prominent trend in the field has favoured the genre of "rational reconstruction," in which the historian tends to rebuild the views and ideas of their source based on criteria of internal logical consistency, and as they should have been presented and articulated to make them relevant for today's audience. This approach dramatically cuts down the need to embark on a painstaking exploration of historical contexts, but at the cost of missing perhaps one of the greatest rewards of historical research proper, which, in Richard Rorty's words, "helps us to recognize that there have been different forms of intellectual life than ours" (Rorty 1984, 51).

The current debate on the methodology of the history of philosophy and science, however, tends to favor the need to take the historical context into serious consideration and avoid a purely anachronistic exercise of rational reconstruction (Roux 2011, 224–230; Smith 2013; Vermeir 2013; Laerke 2013 and 2015; Garber 2015). It has even been argued that contextualism has "won the fight" against rival approaches like pure rational reconstruction (Mercer 2019). This latter claim may sound exaggerated, given that the flow of publications aimed at providing seemingly rational reconstructions of their sources has not stopped in leading journals and with influential presses. To reconcile this point, one might argue that today's historians seem to endorse as *normative* a demand concerning the need to take the historical context into serious consideration, as a fundamental prerequisite for any engagement with historical sources. In practice, however, it has been noted that rational and contextual reconstructions *can* (and perhaps *should*) be blended to various degrees, depending on researchers' aims (Beiser 2016), and this might provide a justification for keeping the contextualist demand at its bare minimum in many concrete cases. While accounting for the simultaneous survival of the genre of rational reconstruction in a climate that, methodologically and normatively speaking, seems more and more inclined toward contextualist research, this sort of compromise disguises a more fundamental pragmatic problem with the contextualist approach itself.

Contextualism requires making two decisions: first, what the primary focus is and, second, how to pick its relevant context. Neither of these decisions is straightforward. Historiographical canons are created precisely to facilitate these decisions. The canon provides both a list of authors and

https://doi.org/10.1017/S0269889725100653 Published online by Cambridge University Press

works that are worth studying as the main focus of attention and a number of other authors that could be used to put each item in some context. Nevertheless, the past few decades of historical research have made it abundantly clear that canons provide a context that is too selective and ultimately non-representative for a proper contextualist understanding of even canonical authors.[1] Much recent research is motivated by a commitment to expanding the existing canon (e.g., Shapiro 2016; Beaney 2018; Sangiacomo *et al.* 2021a) and introducing new authors and works (e.g., O'Neill 1998, Mercer 2017). But with this growth in the number of sources available, it is much less obvious why a scholar should focus on this or that particular author as the main focus of their research. In other words, if one leaves the reassuring narrowness of canons behind, then there are plenty of possibilities to explore, and perhaps even too many possibilities to decide on. Moreover, canons offer preestablished patterns of recognition, which provide not only significant exemplars of past ways of articulating ideas, but also normative paradigms about what, how, and who should take part in the game of ideas. An important political dimension behind the recent dissatisfaction with established canons lies precisely in the way in which the patterns they establish are systematically biased against certain groups (women or non-Europeans, for instance). However, simply expanding canons or creating alternative ones will not suffice. A canon is effective in providing a proxy for contextualist research precisely insofar as it is limited and thus helps the researcher not to sink in the endlessness of potential sources. Alternative (but somehow still limited) canons aimed at the recognition of neglected figures might remedy certain specific biases, but they offer no guarantee of not introducing new ones.

What this overview suggests is that today's historians of philosophy and science are torn between, on the one hand, a normative methodological desideratum that urges them to take historical contexts into serious consideration for the examination of any source, and, on the other hand, the practical difficulty of implementing this demand, either because of the factual limitations of existing canons or because of the difficulty of just exploring the *mare magnum* of potentially relevant sources.

In this paper, we argue that a wise integration of computational approaches with more traditional methods can contribute to alleviating this problem. A simple but powerful first step in this direction consists in looking at contexts as *networks*, or structures of related nodes (texts). The use of network analysis for the study of past ideas and documents is receiving growing attention (Davis *et al.* 1941; Kerschbaumer *et al.* 2020; Valleriani *et al.* 2022), although its implementation in the fields of the history of early modern philosophy and science is still scarce (see exceptions in Bourke 2017; Sangiacomo and Beers 2020; Rossini 2022). This move helps us not only to operationalize the basic demand of looking for the context of a given text (namely, all the other texts that might be related to it based on certain criteria), but also the idea that networks (like contexts) are patterned by the dynamics of recognition, conflict, and competition, which profoundly shape their structure, and which constitute one of the most interesting aspects to uncover in historical research.

Bruno Latour's interpretation of network analysis has emphasized the dynamic nature of networks and how they are constituted by conflict among their actors.[2] The network is interpreted as an associative unit, which is brought together by the way in which its constituents relate to one another (through links). Yet, this unit is based on conflict (controversy), as a network's agents acting in common is grounded on the tension between program (a goal, or a course of action) and

[1]Recent studies on canonical figures usually try to broaden the context in which they are considered in order to better understand their works. To take just a few recent instances, current Spinoza scholarship no longer tries to fit Spinoza in the rationalist camp between Descartes and Leibniz (as the narrative traceable back to Hegel would have it), but rather seeks to understand his thinking in the much more complex and diverse Dutch context (e.g., Douglas 2015, Laerke 2021). This is not a new trend per se, but an approach that has become increasingly more established.

[2]This echoes the emphasis on controversies that has drawn the attention of historians. See, for instance, Laerke 2013 and 2015; Garber 2015.

https://doi.org/10.1017/S0269889725100653 Published online by Cambridge University Press

anti-program (the opposite of a goal or of a course of action). In our case, defending and disseminating a certain approach (say, a "Scholastic" way of dealing with natural philosophy) would constitute a program, while rival attempts (such as those inspired by Cartesian and Newtonian ideas) would count as antiprograms.[3]

However, what is a program and what is an antiprogram "is relative to the chosen observer," (Akrich and Latour 1992, 261) who, in our case, is the historian of philosophy. In Latour's view, action within networks may take place at a distance, which makes the unit of action take note of its own heterogeneity—it relocates and distributes (and thus, translates) the action to various places that each have their own features, but share the same objective or program (in our case, natural philosophy or whatever else we want to emphasize). Thus, the boundaries of networks are permeable, open to exploration; they are the expression of collectives' needs to broaden their unity based on the tension between program and anti-program. Exploration is the way the collective moves through new associations. There are no pre-established associations, or groups. It is the way such associations are formed, the way groups are born, that matters. In our case, thinking about contexts in terms of network analysis helps us both to lay the foundation for a quantitative study of historical contexts and to emphasize how any such context will be characterized by divides, oppositions, or by what we shall henceforth call "rifts" between different trends and tendencies.

The main goal of this paper is to present a computational method that can be used to "parse"—that is, to divide and analyze—a large corpus of works based on their use of language, alongside some preliminary information that can be retrieved from metadata. The goal of the method is to use the available information about the corpus to create broad groups that can work as sub-contexts for better understanding different sorts of works and authors. In turn, this makes it possible to better profile each group and identify its most distinguishing linguistic features, by thus signaling where the potential rifts between them lie. Once these features are clarified, it will eventually become possible to also identify what the most representative works and authors are in each group and which of them could be worth exploring in greater detail. Our method seeks to provide a computational, quantitative scaffolding for the preliminary work of discerning, within a broad corpus of otherwise undifferentiated texts, which ones have the potential to be more relevant for a specific research question and provide a more appropriate context of study. It is important to stress once again that this scaffolding works at the *preliminary* level of research: the integration of computational tools needs to be wise, because computation needs interpretation and it is only when a human reader looks at the results that data become meaningful (and debatable). Part of our interest in this study is thus to show how such a computational method should be implemented, and to map its potential shortcomings.

2. Method

As previously mentioned, a fairly general way of understanding the context of any given source is to think of it as a structure of more or less closely related other texts, which could be deemed relevant for the understanding of the departing source. The methodological challenge consists in operationalizing this rather vague understanding and implementing it in a productive way.

One relatively straightforward solution is to look at how historical texts connect with one another (e.g., Laerke 2013 and 2015; Sangiacomo *et al.* 2021b). Correspondences and controversies are perhaps the most extensively studied and discussed cases. But the relative idiosyncrasy of this kind of corpora shows the urgency of extending this model of linkage beyond explicit references. On the one hand, not all historical sources are linked in this explicit fashion, while, on the other hand, historians might be interested in studying connections that hold between texts regardless of whether or not they are explicitly referring to one another. Explicit links are

[3]According to Madeleine Akrich and Bruno Latour, the anti-programs are "the actions of actants that are in conflict with the programs chosen as the point of departure of the analysis" (1992, 261).

https://doi.org/10.1017/S0269889725100653 Published online by Cambridge University Press

made by authors themselves and are thus based on (and to some extent limited by) their local and historical knowledge of other sources available to them.

But the historian cannot adopt this authorial point of view. Explicit references to authorities might be the result of cultural, social, and political circumstances and do not necessarily entail an actual endorsement of them, nor are early modern authors always committed to full disclosure or even sincerity in their references. More generally, the historian is situated in an entirely different time and place, and has access to sources that might not have been available to the historical actors. In other words, the historian can more easily take a broader, bird's-eye perspective on the historical landscape, and exploit its heuristic potential to gain insights that might have been unavailable to the historical actors themselves. The methodological challenge is to adopt an approach that could potentially take stock of any preexisting explicit linkage between the sources themselves, while also extending this criterion so as to handle any corpus, regardless of whether its constituents are explicitly linked.

One way of rephrasing this challenge is by considering the envisaged method as a tool for putting counterfactual constraints on the way in which the context of a given text is reconstructed. Instead of determining the most likely connections, a contextualist method could also be used to rule out the most *unlikely* connections, or rather to *parse* the corpus by distinguishing different groups of sources within it, and thus indicating where one should look in the search for *likely* allies or likely foes.[4] Traditional historians of philosophy and science already tend to do this by using different ideological labels. For instance, calling a certain author a "Scholastic" or a "Cartesian" carries implications for the expectations that one will then nurture about the likely allies or foes of that author. But these categorizations are usually based on the use of a few selected paradigms that are taken to be representative of a whole group of sources. We argue that this qualitative approach can be fruitfully strengthened and combined with a more quantitative approach based on computational semantic network analysis, which provides ways of measuring the proximity between various potentially relevant sources based on preestablished criteria. We suggest that the method illustrated below contributes precisely to facilitating this measurement.

In order to illustrate the workings of our method, we consider a corpus of 124 early modern printed books (containing just over 1 million words), written in Latin. All these books are either textbooks of natural philosophy or they provide equivalently encompassing and systematic treatment of what "natural philosophy" is about. Chronologically, the corpus spans from 1587 (Nicholas Abraham's *Methodicae Institutiones*) to 1832 (François Jacquier's *Institutionum Philosophicarum Synopsis*). Most of the texts were published in the Dutch Republic, France, and England. All these works are also available in the public domain. Thanks to a specific OCR procedure we developed and implemented (Sangiacomo *et al.* 2022b), we were able to use an enhanced digital transcription of the texts (with a minimum of 90% of word accuracy per page).[5]

Two preliminary worries might need to be dispelled about the choice of this corpus. First, it should be noted our focus on systematic treatises (textbook-like) does not necessarily mean that we are ignoring the most original fronts of the ongoing debate in early modern natural philosophy. While these sorts of work might to some extent be regarded as relatively "conservative," covering a sufficiently broad collection of them, spread over a sufficiently long period (as we do), should be a sufficient guarantee that any relevant ideas that gained traction at some point will eventually be integrated or discussed somehow in more systematic works as well. The data we present below confirms this expectation.[6]

[4]The suggestion is that any computational parsing will only provide an initial statistical expectation, which will have to be checked and corroborated by other means, including an indispensable close-reading of the sources themselves.

[5]This corpus is a selection from a larger inventory of potentially relevant works of early modern natural philosophy, the rationale of which is described at length in Sangiacomo *et al.* 2021b.

[6]In fact, studying early modern natural philosophy from the point of view of university teaching or in connection with the academic milieu is part and parcel of the "contextualist" turn of the last decades. Universities were laboratories for the constant adjustment and transformation of concepts and practices (Schmitt 1983; Leijenhorst, Lüthy, and Thijssen 2002). It is

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Second, since textbooks in particular often include natural philosophy among other fields of study, one might wonder what is the relevance of this corpus for natural philosophy proper. On the one hand, this paper is illustrative in nature, in the sense that we aim to use this corpus to illustrate our method for computational parsing, more than for introducing a new interpretation of the evolution of natural philosophy per se. On the other hand, textbooks are in fact relevant for better understanding this evolution, since they do provide one context (the curriculum of disciplines in which natural philosophy was part), and for better framing the place of natural philosophy in the field of knowledges cultivated during the early modern period (Ariew 2014, 41–105).

The results presented in this paper were derived from a corpus containing a flattened map of intellectual movements, with few pre-established expectations on the part of the observers (researchers). In fact, the corpus includes authors and texts that were largely unfamiliar. From a chronological point of view, it is sensible to say that Cartesian and Newtonian scholars were "anti-programs" (to use Latour's terminology) to Scholastics. However, the computational approach presented here offers hypotheses and results based only on the degree of textual similarity between any two texts, leaving room for further debate about how best to interpret them.[7] As we explain in the following, our network understanding of the corpus in question offers a different vista on the programs and antiprograms of early modern natural philosophy, one that both confirms and contradicts our initial assumptions.

2.1 Network representation

In order to investigate the corpus as a whole, we need to have a relational representation of it. A network is a very common form of mathematical representation that stresses the relational structure of a given reality (Barabási 2016; Newman 2018). Networks are made of two main groups of elements: nodes (vertices) and edges (links). Nodes represent the individual items we want to represent (the books in our corpus as digitized files), while the edges represent the way in which they relate to each other according to specific criteria. A preliminary difficulty we have to overcome is that the inventory of our corpus comes without any consistent information about direct links between works or authors. Therefore, we have to find a way of establishing these links, a common feature that links all of them to a higher or lower extent.

Our approach consists in linking works based on a degree of linguistic similarity (for a more detailed discussion of this methodology see Sangiacomo *et al.* 2022a). In other words, we establish a link between two works insofar as they share a common feature in their use of language. This captures a layman's intuition according to which two books saying similar things in a similar way can be taken to be similar to one another. This similarity might or might not be further examined in terms of historical or intellectual influences among the works under scrutiny. The intuition is relatively easy to operationalize through computational methods, since the field of natural language

increasingly clear that ongoing transformations in the academic milieu created a more fertile background for the spreading of new approaches in natural philosophy (Schmitt 1984; Feingold 1984, 2003; Brockliss 1987; Gascoigne 1989; Sgarbi 2013). A number of Aristotelian authors were open to new developments and accommodated them in the established frameworks taught at universities (Brockliss 1996; Porter 1996; Feingold 1997).

[7]We also share Latour's understanding of the role of digital or computational approaches in this effort of better representing networks. Latour sees here great potential for computationally-derived visualizations to provide horizontal, flattened (non-hierarchical) maps. During his opening plenary lecture for the world ADHO conference at the University of Lausanne in 2014—"Rematerializing Humanities Thanks to Digital Traces" (web)—Latour noted that the digital does not (aim to) create a separate world from what we call the real world, but to "rematerialize all cognitively complex sets of practices," that is, to emphasize only some of the elements of a world that remains "massively real" (Latour 2014). The digital is to him a re-engineering of the real that selectively emphasizes certain aspects of the world in order to enhance its intelligibility. This is also the heuristic goal of the method we propose in the following sections.

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processing (NLP) offers very well-established methods to compare linguistic similarity between text documents from different perspectives (Aletras and Stevenson 2014; Delamaire *et al.* 2019).

The two most common and widespread techniques are topic modelling (TM) and text frequency-inverse document frequency (tf-idf). Topic modelling is an unsupervised statistical model which identifies a number of abstract topics (or a latent semantic structure) in a large collection of texts. A "topic" is a collection of keywords that tend to be used in the same context together. The Latent Dirichlet Allocation (LDA) algorithm (Blei, Ng, and Jordan 2003) generates several topics, with each topic containing a given number of keywords that are relevant for a certain subset of works and less relevant for other subsets. For instance, a topic model containing keywords like *pars, corpus, video, pars, moveo, locus* is counted as different from a topic formed by keywords like *moveo, locus, pars, deus, forma, causa*. The two topics share an overlap in certain keywords (e.g., *locus, pars*), but these keywords have a different weight in each topic, thus differentiating how well each topic applies to any given work. In order to use topics to create links between works, we need to generate relevant lists of keywords for the whole corpus (or subgroups in it, depending on what we study), and then assess how well each of these topics is associated with each book (node) in our network. Any time two works use the same topic, we create a link between them, and depending on the strength of this similarity, we can add a weight (or a value) to the link.[8] This gives us a way of assessing the similarity between different nodes and relating them (creating an edge between them) based on that similarity expressed as a weighted link by the correlation score between any two document vectors (Sangiacomo *et al.* 2022a).[9]

Topic modelling takes into account *all* the words included in a text. This approach might be too coarse grained for capturing more specific discursive similarities connected with specific philosophical approaches; it is conceptually opaque. It seems likely that all philosophers share a common dictionary of words that are always used in a non-specific and non-sectarian way (like *corpus* or *locus*), while they differ in the use of words that are more salient or relevant for articulating a specific approach. In order to capture this aspect and use it to strengthen our similarity analysis, topic modelling is usually best complemented by another computational method, tf-idf (Lee 2019). The latter helps us assess how unique or idiosyncratic each work is in its use of language. The tf-idf algorithm devalues the most common words in the corpus and groups together works that use the same specific words. For instance, if two works both use a very common word like *video*, they will not establish a particularly strong connection (because this is a common word), but if they both use the more specific word *substantialis*, then they will. This method offers yet another way of linking the books in our corpus, thus resulting in a second network. Since these two networks share the same nodes (books) but have different sorts of edges (generated by the two different computational methods), the resulting combination is best interpreted as a multiplex network, namely, a multi-relational network made of several layers in which the nodes are the same (Lee, Min, and Goh 2015).

Overall, in combining these two methods we observe that the corpus is fairly homogeneous and all works are more or less similar or connected with all the other works. This is entirely expected and corroborates the validity of the methods we used: both topic modelling and tf-idf are employed to assess document clustering and we applied them to a corpus made entirely of systematic treatises on the same topic, written in a relatively fixed time and space. However, the fact that the resulting network is homogeneous does not mean that all works are seen as equivalent to one another. What we have described so far is just the underlying methodology and the

[8]All these were achieved using Gensim, an open-source library in Python for unsupervised topic modeling and natural language processing, using modern statistical machine learning (Řehůřek 2009).

[9]There is no data set size benchmark for topic modeling. However, literature indicates that corpora in the hundreds and thousands of documents are sufficient for reliable modeling. As a measure of comparison, topic modeling has recently been applied effectively in the analysis of the archive of inaugural speeches by US presidents (Blanke and Aradau 2021), which is much smaller (797,000+ words) than the corpus proposed in this paper (9,754,604 words).

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preliminary step that allows us now to look more specifically for possible ways of tracing differences and parsing the network.

2.2. A procedure for parsing sources

Similarity is a relational property that is best assessed through comparisons. In order to make comparisons, we need to parcel our network in such a way so as to be able to assess the relative similarity or difference between various books. To do so, we need to find a profitable way of parsing the network (and the corpus) that provides a heuristic point of reference for such comparisons. One obvious way of slicing the corpus is chronological, by grouping works by publication date. However, publication dates are not distributed evenly and relying on them alone runs the risk of creating significant imbalances in how the corpus is divided. More importantly, publication dates might be correlated with different trends and discussions in the subject matter, but this is not necessarily the case, so a chronological parsing of the corpus would tell us very little about the homogeneity or heterogeneity of each chronological group in terms of what they actually discuss.

Instead of taking a chronological approach, we factor in one further piece of information that we can derive from the metadata associated with the inventory of our corpus, namely, from the titles of our works. We observe that while the great majority (87%) has a fairly general title that concerns the discipline of natural philosophy or one of its core topics, a significant 13% include in their titles a direct reference to what we recognize as a canonical authority.[10] By far, the most instantiated authorities (12% of the total Latin corpus) are Scholastic, among whom Aristotle, Aquinas, and Scotus are the most common. Note that for the purposes of this paper, we do not distinguish the *orientation* (pro, contra, or other) of the work towards the authority acknowledged in the title, but simply observe that a certain authority is acknowledged and flagged in the title. Our discussion of authority acknowledgments is thus neutral with respect to whether the authors using these acknowledgments intended to argue in favor, against, or in some other way about the authorities they mentioned.

Existing scholarship has stressed that no historical group of philosophers or school was particularly homogeneous (Garber 2016) and appealing to the same flag or authority allows for a wide range of individual deviation and differentiation. 'Non-Scholastic' authors are perhaps even less homogeneous, as they tend to be unified only by a reference to what they aim to oppose (Garber 2013). From a methodological point of view, our purpose here is not to define what Scholastic or non-Scholastic (Cartesian or Newtonian, for instance) natural philosophy looks like, but rather to derive from the information embedded in our corpus a valid, heuristic way to parse its contents further. We derive this information from explicit mentions in the titles of the works themselves. We then further integrate this information with background information concerning their authors, which we derive from the available bio-bibliographical *Dictionaries* of seventeenth- and eighteenth-century philosophers.[11] The integration of this latter information is required in order to create a group that is sufficiently large to generate meaningful computational results.

This allows us to introduce a first operational distinction between Scholastic (45.6% of the total) and non-Scholastic works (the remaining 54.4%). Note that the use of background information derived from existing scholarship (the *Dictionaries*) increases the group of Scholastic works by 33.6%. However, as documented below, we do not take this figure entirely for granted,

[10]In the broader multilingual corpus from which we derived the current working corpus, 25% of works overtly acknowledge one authority, see details in Sangiacomo *et al.* 2021b.

[11]Wiep van Bunge, Henri Krop, Bart Leeuwenburgh, Paul Schuurman, Han van Ruler and Michiel Wielema, *Dictionary of Seventeenth- and Eighteenth-Century Dutch Philosophers* (London: Bloomsbury, 2003); John Yolton, Valdimir Price and John Stephens. *Dictionary of Eighteenth-Century British Philosophers* (London: Bloomsbury, 1999); Andrew Pyle, *Dictionary of Seventeenth-Century British Philosophers* (London: Bloomsbury, 2000); Luc Foisneau, *Dictionary of Seventeenth-Century French Philosophers* (London: Bloomsbury, 2008); Heiner F. Klemme and Manfred Kuehn, *Dictionary of Eighteenth-Century Philosophers* (London: Bloomsbury, 2011).

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since our method will help us corroborate (or falsify) whether authors originally included in the Scholastic group are indeed homogeneous, and whether there are some hybrid or "fuzzy" cases.

We are thus in a position to use our network representation to address the following two research questions:

(1) To what extent are the Scholastic and non-Scholastic groups homogeneous?
(2) What are the most central works in each group?

Note that both questions are asked from the point of view of the linguistic features of the corpus that we can study with computational methods and hence do not immediately or necessarily concern the philosophical or conceptual nature of the works themselves. But it seems plausible to surmise that a degree of linguistic homogeneity might be positively correlated with a degree of philosophical homogeneity, and linguistic centrality with philosophical centrality (and this hypothesis is falsifiable).

The first question can be used to assess whether and to what extent a certain group constitutes a relatively uniform "context" of works reasonably similar and well-connected with one another. As mentioned, existing scholarship has often stressed the diversity within broader groups, by emphasizing that different Scholastic or Cartesian authors (for instance) might have produced significantly different outputs. But does this mean then that such school labels should be rejected altogether and that they constitute nothing but a conventional umbrella-term for an otherwise heterogeneous set of texts? We argue here that looking at this issue from a linguistic point of view provides a new approach to tackling it.

The second question concerns the problem of selection, or directing attention within a large data set to those particular cases that might be worthier of close scrutiny. In terms of network analysis, this is most commonly done by analyzing centrality measures, namely, various metrics that rank the nodes in a network based on their structural position in the network (i.e., their role in constituting said network). Since centrality is a structural property that results from the way in which the network is shaped, studying centrality measures as a proxy to identify relevant cases for further scrutiny provides a bottom-up approach that can be helpfully integrated with the more top-down attitude of focusing on well-established case studies in existing literature or canons.

In building a network where links between nodes (books) represent similarity relations (either based on TM or on tf-idf), we have two ways of further interpreting these relations. On the one hand, we can simply consider the *strength* of any connection between any two books, which means how similar they look from the point of view of topic or tf-idf vectors. But the fact that two books are strongly connected (strongly similar) does *not* entail that they are also *central* in the network. In the following discussion, we shall take into account two standard centrality measures: eigenvector centrality, and betweenness centrality (Newman 2018). In this context, we interpret eigenvector centrality as expressing the likelihood for a work to be reflective of a topic that is represented in multiple other works. Betweenness centrality expresses instead the ability for a node to create links between different usages of certain topics. From these working definitions it should be clear that centrality cannot be conflated with correlation strength (or degree of similarity), since the latter applies to any two books regardless of their structural position in the network, while centrality depends precisely on that structural position. Distinguishing similarity strength and centrality helps provide different perspectives on the overall network. In the most straightforward way, we can use the average similarity strength as an indicator of homogeneity (research question 1) and centrality as an indicator of structural relevance (research question 2).

However, both aspects are tackled from the point of view of *similarity* measures (or the degree to which works in a certain corpus correlate among each other), which means that our discussion

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is not necessarily going to spot what traditional scholarship has singled out as the most original and outstanding works or authors. On the contrary, these measures will rather emphasize those works and authors that contributed mostly to creating a shared conversation, bridging different approaches and mediating between programs and anti-programs (to use Latour's phrasing). To give an example, although Newton's *Principia* is included in our corpus and it is surely one of the most important works in early modern natural philosophy, it does not appear at all among our top-scoring results, while a relatively more obscure Dutch Newtonian, like Willem 's Gravesande (1688-1742), does. We reflect on this methodological point and on its implications as our discussion unfolds.

However, in order to fully address both our research questions, we need to refine our initial grouping. Obviously, the fact that a work does not include a direct reference to a Scholastic authority in its title, or the fact that we do not know enough about it or its author, does not entail that such a work is not similar to other works we flagged as "Scholastic." This means that our initial parsing based on metadata needs further distillation. To do so, we implement the following three-stage procedure, which will be explained and discussed throughout the following sections.

Stage 1: Analysis of the departing groups. Here, we simply take our two groups ("Scholastics" and "non-Scholastics"), generated on the basis of metadata only, and use network analysis to gain a better understanding of some of their features. We also use this analysis to test what the initial answers to our two research questions would look like if we were to limit our analysis to this stage. Since our network has two layers (one based on topic modelling, henceforth TM, the other based on tf-idf), our analysis will have to proceed on two parallel, but complementary tracks for each group.

Stage 2: Computational parsing. After the preliminary analysis in stage 1, we identify which works in the non-Scholastic group are most similar (based on their network properties) to the works in the Scholastic group. We then move these works to the Scholastic group, leaving the rest in a more distilled non-Scholastic group. This computational parsing process, however, comes with a few unexpected results, which we document below.

Stage 3: Analysis of the updated groups. We repeat the same analysis in stage 1 for the two updated Scholastic and non-Scholastic groups, in order to assess how the computational parsing affected our initial results and what answers to our two research questions we can derive from the revised groupings. In going through this process, we also draw attention to a number of works that emerge as markers for differences and similarities among different groups. We take this last remark as an important, serendipitous finding, which we expand on in our conclusions.

3. Implementation

3.1 Stage 1: Scholastics and non-Scholastics

We begin by splitting the corpus into two groups, Scholastic and non-Scholastic authors, as explained in the previous section. Figure 1 provides a NetworkX visualization[12] (spring layout) of the way in which the two groups appear from the point of view of Stage 1. A file label number was automatically assigned to each text in the corpus.[13]

Starting with TM, we generate four topics that are particularly relevant for the Scholastic group in its initial configuration (i.e., based on direct acknowledgments in the titles, or information derived from the bio-bibliographical *Dictionaries*). We set the number of relevant topics to four based on a computationally determined coherence value, which establishes the most relevant number of topics for a certain collection of documents (Röder, Both, and Hinneburg 2015). The

[12]In Figure 1 and the subsequent ones, the nodes are sized according to their degree (degree-sized nodes). A node that has a lower number of links (irrespective of the strengths of the vectors that connects them) will be smaller than another node which connects to a higher number of other nodes. The differences in weight are reflected in the thickness of the links.

[13]The list of nodes and corresponding files can be consulted on Zenodo (Sangiacomo *et al.* 2021c).

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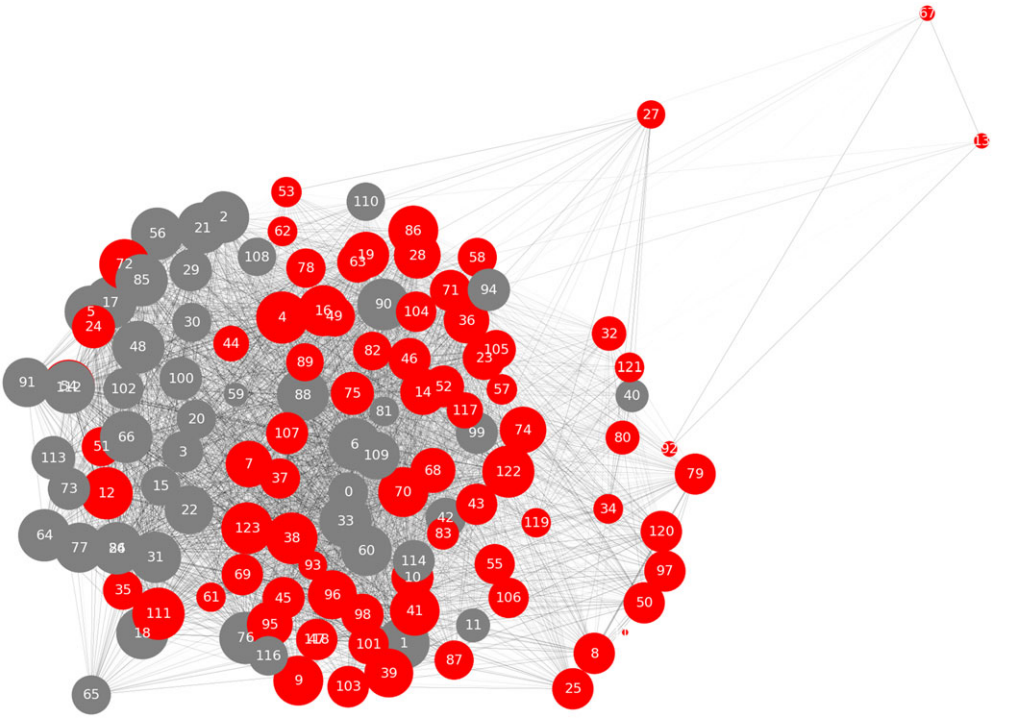

Figure 1. Network of books in the Latin corpus (1587-1832) cf. topic vectors (red = Scholastic authors; grey = non-Scholastic authors).

keywords pertaining to these four purely Scholastic topics are presented in Table 1, while the network configuration of the group is presented in Figure 2.[14]

The keywords reflect the subject matter of natural philosophy (*pars, corpus, ratio, moveo, materia*), but also the specific framework that is common in Scholastic philosophy (*deus, forma, species, virtus*) and the fact that, in this context, natural philosophy is usually dealt with within more encompassing systematic discussions of other subjects as well (hence, keywords like *homo, bonus, voluptas, malus*). However, not every topic has the same relevance to each work.

We observe that all works in this group are very strongly correlated with one another, all between 0.9999 and 0.9861, out of a maximum of 1.00, meaning that they are reflective of the same topics to the same extent. This suggests that this departing Scholastic group is internally cohesive in terms of language usage. The two most strongly correlated works are *Cursus Philosophicus* (1656) by Jean Lalemandet (1591–1647) and *Philosophia Scoti* (1690) by Jean Gabriel Boyvin (1605-1681). Both authors are French Scholastics and neither tends to be considered as particularly original in his own right.[15]

[14]Note that the order in which topics are generated and presented is simply a working order established by the script we used and is not consequential. The value associated to each word in each topic represents a probability, that is, the likelihood for a certain word to be representative within a given topic. The probability values in the LDA model range from 0 (in which all the words have very low probabilities) to 0.011 and are an indication of the extent to which a keyword is relevant for each topic. Also, the fact that, in this case, Topic 2s is the most representative for the corpus in question, means, on the one hand, that it has the highest number of documents associated to it and, on the other, that it ranks as the most relevant topic for most of these documents.

[15]Cf. entries for Lalemandet and Boyvin in Foisneau 2015, 951–952 and 354, respectively.

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Table 1. Topics in the Scholastic flag group (with Topic 2s being the most representative)

Topic 1s		Topic 2s		Topic 3s		Topic 4s	
pars	0.010	ratio	0.009	moveo	0.009	voluptas	0.003
corpus	0.009	pars	0.007	locus	0.005	virtus	0.003
video	0.006	deus	0.007	pars	0.005	bonus	0.003
ratio	0.005	homo	0.006	deus	0.005	ratio	0.002
moveo	0.004	species	0.005	forma	0.005	honor	0.001
locus	0.004	forma	0.004	causa	0.005	malus	0.001

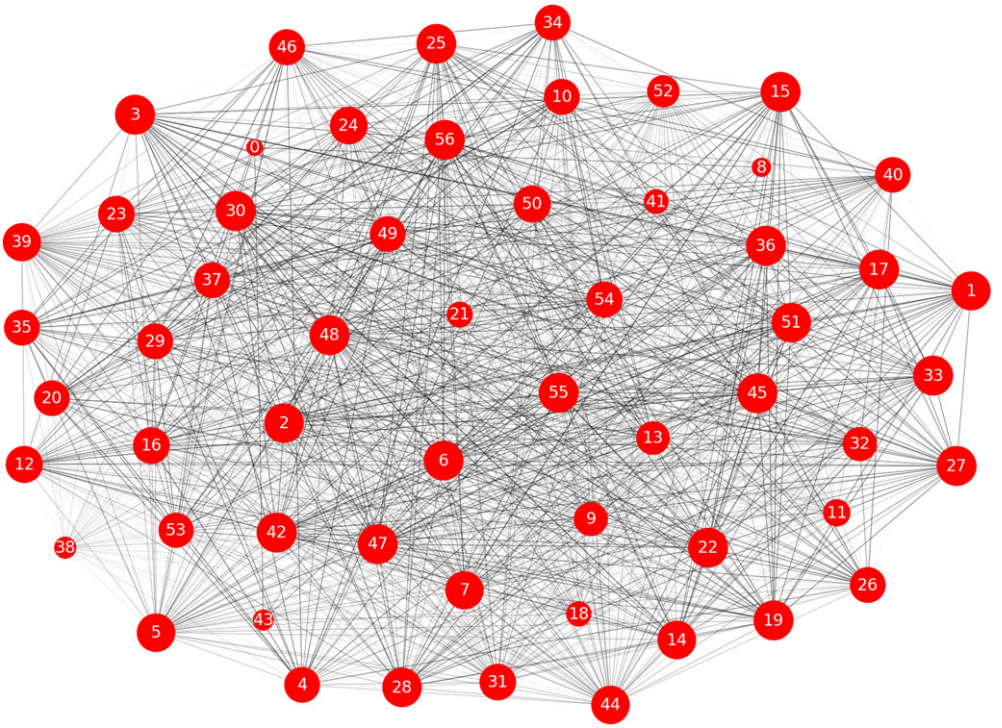

Figure 2. Network of Scholastic authors writing in Latin (1587-1832) cf. topic vectors.

Table 2 plots the top-scoring works in both eigenvector and betweenness centrality in the two network layers.[16] In this respect, it is worth mentioning that there are only a few titles in each corpus presenting non-trivial betweenness centrality and, therefore, the likelihood to have acted as bridges between certain pairs of works.

Top-ranking nodes in terms of eigenvector centrality are almost all seventeenth-century French Scholastics, strongly associated with topic 2s, which is the one that includes almost no keywords directly relevant to the description of natural phenomena as such. We also observe that the top-ranking works (by Boyvin and Columbus) are of Scotist orientation, suggesting that this might be

[16]All betweenness top rankings in the case of our corpus present a much lower number of non-trivial entries than eigenvector centrality scores.

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Table 2. Top ranking nodes in eigenvector and betweenness centrality in the topic and tf-idf layers

	TM		TFIDF	
	Eigenvector	Betweeness	Eigenvector	Betweeness
1.	**1690_BOYVIN**, *Philosophia Scoti* (node 0)	**1600_CASE**, *Lapis philosophicus* (node 16)	**1739_FRASSEN**, *Philosophia academica* (node 9)	**1660_CHABRON**, *Philosophia per breviter argumenta explicata* (node 20)
2.	**1669_COLUMBUS**, *Novus cursus philosophicus Scotistarum* (node 49)	**1649_BASSON**, *Philosophiae naturalis adversus Aristotelem libri XII* (node 15)	**1655_FOURNENC**, *Universae philosophiae synopsis* (node 50)	**1622_BURGERSDIJK**, *Idea philosophiae naturalis* (node 25)
3.	**1656_LALEMANDET**, *Cursus philosophicus* (node 38)	**1681_SEMERY**, *Triennium philosophicum* (node 29)	**1671_RHODES**, *Philosophia peripatetica* (node 47)	**1723_ODÉ**, *Oratio de laudabili proscorum hominum methodo* (node 33)
4.	**1616_FABRI**, *Philosophia naturalis* (node 26)	**1631_BURGERSDIJK**, *Idea philosophiae* (node 52)	**1644_DEUSING**, *Naturae theatrum universale* (node 51)	
5.	**1692_CAUVIN**, *Cursus philometaphysicus* (node 4)	**1690_BOYVIN**, *Philosophia Scoti* (node 0)	**1645_KYPER**, *Institutiones physicae* (node 14)	
6.	**1639_AbraDeRACONIS**, *Totius philosophiae brevis tractatio* (node 41)	**1670_PINY**, *Cursus philosophicus Thomisticus* (node 34)	**1656_LALEMANDET**, *Cursus philosophicus* (node 38)	
7.	**1692_DuPASQUIER**, *Summa philosophiae acholasticae et Scotistae* (node 8)		**1652_SENGUERDArnold**, *Collegium physicum* (node 56)	
8.	**1660_CHABRON**, *Philosophia per breviter argumenta explicata* (node 20)		**1650_ISENDOORN**, *Medulla physicae* (node 31)	
9.	**1665_GAUTRUCHE**, *Institutio totius philosophiae* (node 53)		**1615_JACCHAEUS**, *Institutiones physicae* (node 28)	
10.	**1649_COMPTON**, *Philosophia universa* (node 35)		**1618_CRASSOT**, *Physica* (node 5)	

a dominant trend among French Scholastics. In this context, natural philosophy is presented as a parcel of a broader curriculum, most commonly within multi-volume works that also include sections on metaphysics, logic, and ethics. This means that we have a group of French Scholastic works acting as an influential pole in both disseminating and reiterating a certain way of presenting and discussing natural philosophy during the period. If this is correct, then topic 2s might also be used for detecting more Scholastic works in our corpus, as we shall illustrate below.

Betweenness centrality helps us better understand how the cluster of French Scholastics might relate to other parts of the Scholastic group. French Scholastics (Semery, Boyvin, Piny) are still very present among the most high-raking authors in betweenness. But we also find non-French Scholastics, such as Case (one of the few British Scholastic authors) and Burgersdijk (one of the forefathers of Dutch Scholastics), or French anti-Scholastics such as Sébastien Basson (b. 1573), who engaged with Aristotelian natural philosophy, but for the sake of *criticizing* it (cf. Lüthy 1997). This reminds us that our initial Scholastic group does not necessarily encompass only authors that advocated Scholastic natural philosophy, but also those who explicitly criticized it, while retaining most of its jargon and way of discussing the subject. In the case of Basson, we can correlate this observation with the fact that the most relevant topic for his discussion is 1s (one of the most relevant for a description of natural phenomena). For Burgersdijk and Case, topic 2s (the flagship topic of French Scholastics) is decisively less relevant. This corroborates the intuition that differences in the relevance of a topic for a particular author might be positively correlated with their role in the overall network and the specificity of their philosophical project.

The tf-idf network layer provides a different, and yet complementary picture about the corpus. French Scholastics appear here on a par with Dutch authors, suggesting that in their manner of writing they were comparatively similar. Combined with the topic analysis mentioned above, this indicates that French Scholastics might have been the most direct source or reference for Dutch authors, despite the religious divide between the two groups. In terms of eigenvector centrality, the top-ranking author is still a French Scholastic, though a later one, namely Claude Frassen (1620-1711), who is "generally considered as the foremost seventeenth-century French Scotist" (in Foisneau 2015, 748), while Lalemandet still ranks sixth. The emerging picture is thus that of a tightly connected and homogeneous group (research question 1), dominated mostly by French Scotists (research question 2). This also confirms that our initial move of creating the Scholastic group by relying on both authority acknowledgements in the titles and information derived from secondary scholarship (*Dictionaries*) does produce a homogeneous group.

Moving on to the non-Scholastic group of authors, we generated eight other topics that map their works thematically, as shown in Table 3.

While there is some overlap in keywords among different topics in the Scholastic and non-Scholastic groups, the non-Scholastic topics are overall quite diverse. The list of keywords in the latter group tends toward a stricter natural philosophy lexicon (including elements like *corpus, natura, motus, aqua, ignis*, or more technical terms like *tempus, aequal, radius, ratio, velocitas*).

In the TM layer, the first six most correlated works (mostly correlated among themselves) are by eclectic authors with some Scholastic background or influence (Le Clerc, Du Hamel, Cally, Bootius). Immediately after come the works by Dutch Newtonians (Swinden and 's Gravesande). This suggests that while Newtonians do cluster together, the rest of the non-Scholastic group tends to be relatively heterogeneous and the most related works are by authors that do not necessarily fit a clear-cut category. This can either reflect a property of the works themselves, or (as we will discuss in step 3 below) be partially due to the fact that our grouping of the "non-Scholastics" needs further refinement.

In the top-scoring works for eigen centrality (Table 4) we can easily discern that Descartes plays a powerful role in the non-Scholastic group. Out of the ten highest ranking works, Descartes and his interlocutors or followers (Geulincx, Clauberg, DeRaey, Bayle) take six spots. The others can be identified as Scholastics.

https://doi.org/10.1017/S0269889725100653 Published online by Cambridge University Press

Table 3. Topics in the non-Scholastic group (with Topics 3ns and 8ns being the most representative)

Topic 1ns		Topic 2ns		Topic 3ns		Topic 4ns	
corpus	0.006	corpus	0.003	senatus	0.011	corpus	0.010
natura	0.005	pars	0.003	tempus	0.011	pars	0.010
pars	0.004	deus	0.002	corpus	0.009	motus	0.009
homo	0.004	ratio	0.001	ratio	0.007	aqua	0.005
video	0.003	motus	0.001	aequal	0.007	terra	0.004
magnus	0.003	locus	0.000	centrum	0.007	ratio	0.004
Topic 5ns		**Topic 6ns**		**Topic 7ns**		**Topic 8ns**	
corpus	0.020	bonus	0.006	deus	0.013	corpus	0.021
pars	0.009	deus	0.006	mens	0.011	motus	0.016
radius	0.007	homo	0.005	homo	0.008	pars	0.013
velocitas	0.007	ratio	0.003	pars	0.006	ratio	0.005
fluidus	0.005	voluntas	0.002	corpus	0.006	deus	0.004
gravitas	0.005	malus	0.002	ratio	0.005	unus	0.004

Remarkably, we also observe a complete convergence in terms of topic towards 8ns. This needs to be interpreted cautiously, since the same topic is prominent among works conversant with Cartesian ideas and among some Scholastics. We suggest that some of the Scholastic works strongly associated with this topic might be regarded as performing a bridging role, between Cartesian and non-Cartesian conversations.

The betweenness ranking shows a rather heterogeneous group, both in terms of topics and philosophical orientations. A play of brokerage between new ways of conceiving of natural philosophy and more Scholastic forms becomes more apparent. Bacon shows up here as a relevant author, as historians of philosophy and science are accustomed to consider him a forefather of the new anti-Scholastic approach that evolved in the seventeenth century. But we also have works by Gregory (a British Newtonian) and Nicolas-Louis de Lacaille, who was a deacon but mostly devoted to experimental observations in astronomy. This suggests a marked interest in a more autonomous discussion of natural phenomena, which might well have constituted a common territory for the interplay between Scholastic and non-Scholastic interpretations. The presence of Du Hamel and Pourchot in the top-ranking betweenness supports this intuition, since both authors were committed to hybridizing otherwise traditional Scholastic philosophy with new emerging approaches (especially Cartesian). Pourchot wrote a widely used textbook of Scholastic philosophy, but with ample openings to Cartesian and more recent discussions. In natural philosophy, for instance, his book draws from the atomism of Gassendi and defends the Copernican system (in Foisneau 2015, 1426). Du Hamel is also known for his work as "a mediator between supporters and foes of Aristotelian philosophy" (in Foisneau 2015, 601).

As far as the tf-idf layer is concerned, we find the strongest correlation between the works by Musschenbroek (a leading Dutch Newtonian) and Le Clerc (99.99% correlation). In terms of eigenvector ranking, Cartesian authors (Le Grand, Clauberg) are at the top of the score list. We also notice here a certain mélange between Dutch and French authors. By contrast, when we look at betweenness centrality, the top-ranking works are by authors belonging to religious orders, but active or involved in discussing new trends in natural philosophy. These include Antoine Séguy (fl. 1730?) who, like Pourchot, was active in discussing Cartesian natural philosophy, the already mentioned de Lacaille, and François Jacquier (1711-1788), an influential Jesuit commentator of

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Table 4. Top ranking nodes in eigenvector and betweenness centralities in the departing non-scholastic group

	Topic vector layer		Tf-idf vector layer	
	Eigenvector	Betweenness	Eigenvector	Betweenness
1.	**1688_GEULINCX**, *Compendium physicae* (node 48)	**1723_GRAVESAND**, *Philosophiæ Newtonianaes institutiones* (node 29)	**1664_CLAUBERG**, *Physica* (node 36)	**1832_JACQUIER**, *Institutionum philosophicarum synopsis* (node 55)
2.	**1699_LINGEN**, *Medulla tripartita philosophiae veteris* (node 12)	**1623_BACON**, *De augmentis scientiarum* (node 34)	**1672_LeGRAND**, *Institutio philosophiae* (node 67)	**1762_DeLaCAILLE**, *Ad lectiones elementares astronomiae etc.* (node 54)
3.	**1705_LINGEN**, *Cursus philosophicus* (node 7)	**1757_DeLaCAILLE**, *Lectiones elementares astronomicae etc.* (node 14)	**1694_SPERLETTE**, *Physica nova* (node 51)	**1783_SEGUY**, *Philosophia ad usum scholarum accommodata* (node 65)
4.	**1664_CLAUBERG**, *Physica* (node 35)	**1702_GREGORY**, *Astronomiae physicae et geometricae elementa* (node 38)	**1722_SERRURIER**, *Physicae experimentis innixae tractatio* (node 2)	**1587_ABRAHAM**, *Methodicae institutiones* (node 18)
5.	**1664_DESCARTES**, *Le Monde* (node 19)	**1620_BACON**, *Novum organum scientiarum* (node 36)	**1654_DeRAEY**, *Clavis philosphiae naturalis* (node 23)	
6.	**1654_DeRAEY**, *Clavis philosphiae naturalis* (node 23)	**1681_DuHAMEL**, *Philosophia vetus et nova* Vol 5 (node 11)	**1687_SCHWEITZER**, *Compendium physicae aristotelico Cartesianae* (node 62)	
7.	**1644_DESCARTES**, *Principia philosophiae* (node 3)	**1711_POURCHOT**, *Institutiones philosophicae* Vol 4 (node 59)	**1708_ANDALA**, *Exercitationes academicæ in philosophiam primam et naturalem* (node 44)	
8.	**1671_SANDERSON**, *Physicae scientiae compendium* (node 26)		**1688_GEULINCX**, *Physica vera* (node 59)	
9.	**1700_BAYLE**, *Institutiones physicae* (node 10)		**1733_POURCHOT**, *Institutiones philosophicae* vol 2 (node 4)	
10.	**1746_DAGOUMER**, *Philosophia ad usum scholae* (node 52)		**1695_LeCLERC**, *Physica sive de rebus corporeis* (node 45)	

Newton active mostly in Italy and Spain. Another interesting author that emerges is Nicholas Abraham, sieur de La Framboisière (1560–1636), who was a physician singled out in recent scholarship as witnessing "that Aristotelianism was on the way out in early modern medicine, just as it was in the physical sciences of the period" (Shapiro 2003, 426). So, unlike the eighteenth-century figures mentioned above, Abraham represents a trend similar to that of Basson (i.e., early critics of Scholastic philosophy) and parallel to the more famous case of Descartes.

This preliminary analysis of the non-Scholastic group thus reveals that it is fairly heterogeneous (research question 1): it contains a number of works that could be classified as Cartesian or Newtonian in orientation, but also a variety of important works (from a network point of view), which play a prominent bridging role between Scholastic and non-Scholastic orientations. Those works that stand out as marking the above-mentioned distinctions are precisely the ones that would be worth investigating more closely (research question 2).

3.2. Stage 2: Computational parsing

In order to proceed further with a computational parsing of the groups we constituted during stage 1, we must first study the whole corpus in order to identify which of the works currently tagged as "non-Scholastic" relate more closely to those we tagged as "Scholastic."

Starting once again with TM, we generate a new list of topics that apply to the whole corpus, as illustrated in Table 5.

While there are some overlaps between the keywords in various topics compared to the lists of topics generated in stage 1, we observe that, overall, the keywords included in the topics generated for the whole corpus blend both Scholastic-specific terminology (*deus, quaestio, genus, forma*) and more technical terminology (*pars, corpus, ratio*).

Table 6 shows the top-ranking works in eigenvector and betweenness centrality in the whole corpus, plotting them against the most relevant topics (from Table 5). We observe that topic 3w is shared by all top-ranking works in eigenvector centrality, while top-ranking works in betweenness centrality have a more mixed topic profile. Top-ranking works in eigenvector centrality tend also to be connected with Cartesian natural philosophy, while most of the top-ranking works in betweenness centrality have more a Scholastic orientation. Le Clerc is eclectic (and Newtonian) in orientation when it comes to natural philosophy, while Du Hamel, Regius and Geulincx are all conversant with Descartes. The only Scholastic-oriented authors included in the top ten are in fact Du Hamel and Pourchot, who we already encountered as eclectic Scholastics. This suggests that topic 3w can be used to profile potential "non-Scholastic" works.

The case of top-ranking works in betweenness centrality is less clear cut, also because this measure is associated with a bridging activity between different orientations, and thus the use of topics is expected to be more mixed. Nonetheless, some regularity emerges: topic 2w is prominent only in 's Gravesande (the only Newtonian in the group, and the top-ranking author in betweenness), while topic 5w is shared by both some Scholastics (Crassot) and non-Scholastics (Abraham, Bacon), and topic 8w is associated with more traditional Scholastic works, and in particular French Scotists (Boyvin, Cauvin, Columbus, Crassot). This suggests that topic analysis can be an important proxy for better profiling the role and nature of the most relevant works in a corpus.

Looking at the same corpus from the point of view of tf-idf (Table 7) we once again observe both Scholastics and Cartesians as the most central works: Frassen (Scholastic), LeGrand and Clauberg (both Cartesians) are the top-ranking in terms of eigenvector centrality, while Jaquier and De Lacaille are the top-ranking in betweenness, suggesting again that natural philosophers belonging to religious orders might have acted as important brokers between Scholastics and non-Scholastics (especially Newtonians).

In order to further distinguish which of the works that we initially tagged as "non-Scholastic" might be most similar to the works we identified as "Scholastic," we use a relatively simple

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Table 5. Topics in the whole corpus (with topic 8w the most representative marked in dark gray, followed by topics 5w, 3w lighter gray, and 2w light gray)

Topic 1w		Topic 2w		Topic 3w	
corpus	0.000	corpus	0.016	corpus	0.015
pars	0.000	motus	0.011	motus	0.014
ratio	0.000	pars	0.010	pars	0.011
forma	0.000	tempus	0.006	omnis	0.008
homo	0.000	ratio	0.006	video	0.006
materia	0.000	locus	0.005	aqua	0.005
Topic 4w		**Topic 5w**		**Topic 6w**	
scot	0.006	pars	0.007	senatus	0.011
oppono	0.004	bonus	0.005	ratio	0.007
verd	0.003	homo	0.005	convenio	0.007
locus	0.003	virtus	0.005	nego	0.006
doct	0.003	deus	0.005	pateo	0.006
corpus	0.003	natura	0.004		
Topic 7w		**Topic 8w**		**Topic 9w**	
pars	0.001	ratio	0.010	pars	0.001
corpus	0.000	deus	0.009	deus	0.000
ratio	0.000	pars	0.008	corpus	0.000
deus	0.000	homo	0.007	ratio	0.000
homo	0.000	species	0.006	homo	0.000
materia	0.000	forma	0.006	forma	0.000

algorithm: (i) identify, for each work in the non-Scholastic group, the strongest and weakest correlations in the TM layer and the strongest correlation in the tf-idf layer;[17] (ii) if the strongest correlation is to another work identified as "Scholastic" (and the weakest to a work not identified as such), then count that work as "Scholastic"; (iii) remove the newly identified "Scholastic" works from the "non-Scholastic" group and move them to the "Scholastic" group. Appendix 1 shows the results of this procedure for the works that this algorithm identifies as "Scholastic."

There are two striking features in the results we obtained: the first concerns some of the authors that our algorithm identifies as "Scholastic," while the other concerns the works used to establish this conclusion. Let us consider each feature in turn.

We can clearly identify two sub-groups in the list we obtained. One is constituted by relatively clear-cut cases of Scholastic authors, while another group (marked in grey color in Appendix 1) includes more eclectic works (some of which we already encountered) and some prima facie unexpected names.

At first sight, something seems to go wrong with the algorithm, since canonical *novatores* like Bacon and Hobbes are classified as "Scholastics." This is not the only such case. We already encountered Nicholas Abraham, an early physician who moved away from Aristotelianism. Also, Pourchot was broadly working in the framework of Scholastic philosophy, though he eventually

[17]The difference between the strongest and the weakest correlation scores of any author in the tf-idf layer is not very high (generally under 20%), which renders the lowest correlation scores less relevant.

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Table 6. Top-ranking works in eigenvector and betweenness centrality in the TM layer (whole network)

	Eigenvector centrality in TM layer		Betweenness centrality in TM layer	
	Title	Topic(s)	Work	Topic(s)
1.	**1695_LeCLERC**, *Physica sive de rebus corporeis* (node 77)	3w (99.9%)	**1723_GRAVESAND**, *Philosophiæ Newtonianaes institutiones* (node 48)	2w (99%)
2.	**1678_DuHAMEL**, *Philosophia vetus et nova* (Vol. 4) (node 66)		**1619_CRASSOT**, *Totius philosophiae peripateticae corpus* (node 34)	5w (64%) 8w (35%)
3.	**1646_REGIUS**, *Fundamenta physices* (node 73)		**1623_BACON**, *De augmentis scientiarum* (node 59)	5w (95%)
4.	**1644_DESCARTES**, *Principia philosophiae* (node 3)		**1587_ABRAHAM**, *Methodicae institutiones* (node 27)	5w (82%) 8w (17%)
5.	**1722_CLERC**, *Opera philosophica* (vol. 3) (node 26)		**1669_COLUMBUS**, *Novus cursus philosophicus Scotistarum* (node 115)	3w (22%) 8w (72%)
6.	**1688_Geulincx**, *Physica vera* (node 102)		**1692_CAUVIN**, *Cursus philometaphysicus* (node 13)	6w (31%) 8w (68%)
7.	**1681_DuHAMEL**, *Philosophia vetus et nova* (vol. 5) (node 18)		**1690_BOYVIN**, *Philosophia Scoti* (node 8)	8w (99%)
8.	**1751_POURCHOT**, *Institutiones philosophicae* (vol. 3) (node 24)			
9.	**1664_DESCARTES**, *Le Monde* (node 29)			
10.	**1658_SENGUERD**, *Physicae exercitationes* (node 72)			

Table 7. Eigenvector and betweenness centrality rankings in the tf-idf vector layer (whole network)

	Top ranking nodes in eigenvector centrality	Top ranking nodes in betweenness centrality
1.	**1739_FRASSEN**, *Philosophia academica* (node 28)	**1832_JACQUIER**, *Institutionum philosophicarum synopsis* (node 93)
2.	**1672_LeGRAND**, *Institutio philosophiae* (node 116)	**1762_DeLaCAILLE** *Ad Lectiones elementares astronomiae etc.* (node 91)
3.	**1664_CLAUBERG**, *Physica* (node 60)	**1783_SEGUY** *Philosophia ad usum scholarum accommodata* (node 113)
4.	**1694_SPERLETTE**, *Physica nova* (node 88)	**1660_CHABRON** *Philosophia per breviter argumenta explicata* (node 50)
5.	**1647_STIER**, *Praecepta doctrinae logicae* (node 86)	

defended more Cartesian and atomist ideas in the context of natural philosophy. DuHamel is another author of broad Scholastic orientation who nonetheless engaged occasionally with Descartes and criticized him. Le Clerc represents yet another interesting case. Initiator of important seventeenth-century journals (*Nouvelles de la République des Lettres*, *Bibliothèque universelle et historique*), he is mostly a theologian, but in his more philosophical works, like the one included in this corpus, he presents Cartesian views, alongside those of Locke and Newton, explicitly. The fact that he is ranked as a Scholastic in this case might be due again to his way of writing rather than to the conceptual content of his works. Furthermore, his work is in four volumes: the first three devoted to more philosophical topics (logic, ontology, and "pneumatology" or philosophy of mind), while the fourth is dedicated to natural philosophy proper. In this case, the strongest correlation goes to the Dutch Newtonians explicitly, showing his non-Scholastic orientation in this domain. The same split happens in the case of Pourchot's volumes.

We also observe that comparing TM and tf-idf results helps further balance the outputs based on TM. Hobbes and Bacon, for instance, correlate more strongly in the tf-idf layer with later Cartesians (Le Grand and Clauberg) rather than with more traditional Scholastics. This suggests that in the specific way in which they use language, they are more akin to later generations of non-Scholastics, *or* (inclusive) that these later generations drew from them more than from the more traditional Scholastics (both options are accepted in existing scholarship).

Generalizing, we can draw the following conclusion: In the early seventeenth century (Abraham, Bacon, Hobbes), the divide between "Scholastic" and "non-Scholastic" is hardly traceable in terms of topics or linguistic features. Authors engaging with natural philosophy tend to share a broad way of talking about the subject and their divisions emerge within this shared background. This background is not something to be left behind in the past, but actually something that remains in place throughout the period covered by our corpus and shows up in relatively late figures like Le Clerc and Pourchot, which sit in between the two "worlds."

The fact that Bacon and Hobbes are strongly correlated with Scholastic works, especially in terms of the topics they use, should not come as a surprise at a second glance. Despite how vocal both authors are in their fight against Scholastic philosophy, our methods look mostly at the use of Latin in their works and, from this point of view, it appears that Bacon and Hobbes did not write very differently from later Scholastic authors (especially Scotist Columbus and the Dutch Senguerd). Given that the strongest correlated works are all later in terms of publication dates, this

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Table 8. Authors and works that establish the largest number of strongest and weakest correlations in the whole Latin corpus

Authors	No. of strongest Correlations TM	No. of weakest correlations TM	No. of strongest correlations TF-IDF
1690_BOYVIN, *Philosophia Scoti*	57	0	3
1631_BURGERSDIJK, *Idea philosophiae*	32	0	0
1723_GRAVESAND, *Philosophiæ Newtonianaes institutiones*	12	17	1
1757_DeLaCAILLE, *Lectiones elementares astronomicae etc.*	6	19	1
1646_REGIUS, *Fundamenta physices*	27	0	10
1672_LeGRAND, *Institutio philosophiae*	0	0	9
1739_FRASSEN, *Philosophia academica*	0	0	8

might also be interpreted as a hint at the fact that a certain way of writing specific to Bacon and Hobbes might have filtered into later Scholastic works.

Note that our purpose here is not to define a paradigm for what a "Scholastic" author looks like, but rather to use NLP methods in order to group together works based on their similarity in the use of language. From this point of view, our method smooths out the traditional stark contrasts between Scholastic and some of the most vocal non-Scholastic authors, showing that both groups spoke to one another in a fairly similar way. This approach thus lends support to the hypothesis that innovation, especially in the early seventeenth century, was not introduced via a new way of speaking or writing, but rather by reshaping from within what was, at the time, accepted academic (Scholastic) language.[18] And to take this intuition even further, we surmise that not only might have innovative ideas been clothed in otherwise traditional (Scholastic) language, but, more importantly, this use of a relatively traditional language to spread relatively new and non-traditional ideas positively fostered their dissemination. In other words, the use of Scholastic language made innovative ideas more intelligible for a larger educated audience (even when the authors' intention might have been to criticize those ideas), thus contributing to their normalization in the long term.

From a more methodological point of view, we also stress that comparing between TM and tf-idf is particularly helpful, since it provides a way of double-checking associations created by one single method. More importantly, topic associations are themselves rather consistent, with topics 1w and 8w being the most relevant for determining any association with Scholasticism. But notice that while Topics 5w and 8w might well include keywords with a Scholastic ring, topic 3w seems entirely attuned to the subject matter of natural philosophy. Hence, the ideological connotation of any topic is something that emerges mostly at the level of interpretation, when we look at who the authors that used that topic mostly are.

The second feature worth commenting on, and perhaps the most striking and unexpected result of this approach, is that only a few authors consistently show up as the strongest or weakest correlations for all the others. Table 8 below presents them in detail, across the two layers.

[18]For a case study of how controversy entails shared linguistic background, see Jesseph 1999.

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Boyvin is a particularly interesting author, since the works strongly correlated with him and weakly correlated with 's Gravesande tend to show a Scholastic orientation. Dutch Scholastics with a Cartesian interest, like Burgersdijk and Regius, operate instead as potential markers for more eclectic Scholastic authors (like Pourchot). The situation is more fluid in the case of the strongest tf-idf vector correlations, which show greater variety. However, we can still discern a tendency among the more clear-cut cases of Scholastic works to correlate strongly with likewise clear-cut Scholastic works (like Frassen), while less-clear cut cases tend to correlate strongly with equally eclectic (or Cartesian) works (like Le Grand).

There is also something peculiar with 's Gravesande *Institutiones*, since this single title shows up consistently as a marker (negatively or positively) in both Scholastic and non-Scholastic groups (as illustrated below). One might wonder whether something is going wrong here, since this work deals mostly with what others would have called the "mathematical sciences" and has only a first introductory part dealing with conventional natural-philosophical topics. One might thus interpret this as a book by a professor of mathematics dealing mostly with issues belonging to mathematics. However, this is not a reason to dismiss the book, but instead offers an incentive to take a closer look at it (although doing so is beyond the scope of this paper). The fact that 's Gravesande's *Institutiones* are not entirely focused on various topics usually included within natural philosophy is not different from what happens in other multi-volume works in our corpus. In fact, it is a recurrent feature of early modern natural philosophy at large to be discussed in the context of other subjects as well. Moreover, our method is sensitive not to the various concepts that are dealt with, per se, but to the way in which language is used to express them. Hence, the consistency with which 's Gravesande's work shows up in our results points to the fact that 's Gravesande's use of language in this work is particularly helpful in parsing different approaches to natural philosophy, even if that is not the primary aim of 's Gravesande himself as an author. This is one instance of the heuristic potential of "distant reading," through which the computational method might detect features of a text that a human reader might not be able to recognize or even pay attention to.

In terms of our research questions, this fact suggests that network analysis has the potential to uncover a number of authors who operate as potential markers for different orientations within the whole network. We shall come back to this observation in our conclusions.

3.3 Stage 3: The updated groups[19]

When we remove the above-mentioned works (Appendix 1) from the non-Scholastic group, we obtain the updated version of the same group, which we present in Appendix 2, by showing also the strongest correlations in the TM and tf-idf layers.

This updated version of the non-Scholastic group now reveals a much clearer profile, showing the presence of two rival (and expected) trends: a rather consistent group of works conversant with Descartes's philosophy (Regius, Cally, De Raey, Geulincx, Le Grand, Andala, Clauberg), and a group of works more connected with Newton ('s Gravesande, Musschenbroek, van der Eyck, Swinden, De Lacaille, Gregory). Figure 3 shows the distribution of Scholastic and non-Scholastic works before and after the computational parsing.

When we look at eigenvector centrality, it seems that the dominant group is the Cartesian one (Table 9), as we already noticed at stage 1, although the names and their scores have changed slightly with respect to the previous Table 4. Perhaps the most visible difference is that Descartes himself now tops the ranking.

[19]In presenting the results for stage 3 of our procedure (§2.2 above), we emphasize those obtained for the non-Scholastic group, since this shows the most significant overall changes. Results for the updated Scholastic groups will be mentioned below in an abridged form.

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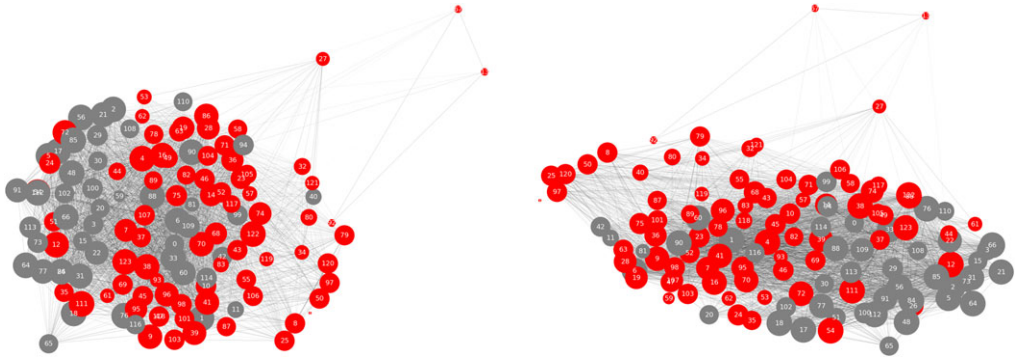

Figure 3. Whole corpus before (left) and after (right) parsing (red = Scholastic, grey = non-Scholastic).

Table 9. Eigenvector and betweenness centrality in the remaining non-flag group cf. topic modelling

Rank	Top ranking nodes in eigenvector centrality	Top ranking nodes in betweenness
1.	**1664_DESCARTES**, *Le Monde* (node 13)	**1757_De la CAILLE**, *Lectiones elementares astronomicae etc.* (node 11)
2.	**1644_DESCARTES**, *Principia philosophiae* (node 3)	**1786_SWINDEN**, *Positiones physicae* (node 38)
3.	**1664_GREYDANUS**, *Institutiones physicae* (node 1)	**1671_FABRI**, *Physica* (node 12)
4.	**1688_GEULINCX,** *Physica vera* (node 35)	**1674_CALLY**, *Institutio philosophiae* (node 6)
5.	**1678_DuHAMEL**, *Philosophia vetus et nova* Vol 4 (node 24)	**1695_CALLY**, *Universae philosophiae institutio* (node 17)
6.	**1646_REGIUS**, *Fundamenta physices* (node 25)	**1723_GRAVESAND**, *Philosophiæ Newtonianaes institutiones* (node 18)
7.	**1700_BAYLE**, *Institutiones physicae* (node 8)	**1641_BOOTIUS**, *Philosophia naturalis reformata* (node 28)
8.	**1695_LeCLERC**, *Physica sive de rebus corporeis* (node 27)	
9.	**1708_ANDALA**, *Exercitationes academicæ in philosophiam primam et naturalem* (node 26)	
10.	**1746_DAGOUMER**, *Philosophia ad usum scholae* (node 32)	

In terms of betweenness centrality, authors with a strong interest in astronomy and Newtonian natural philosophy seem to take the foreground (De Lacaille, Swinden, 's Gravesande), as do authors who engage critically and eclectically with the Scholastic heritage (Bootius and Fabri), including a declared Cartesian (Cally). The results here are not particularly different from those at stage 1 (Table 4).

Moving on to the tf-idf layer (Table 10), we observe that the presence of Cartesian authors is much more solid and apparent, and they top all rankings in both the TM and tf-idf layers. In this

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Table 10. Eigenvector centrality and degree in the remaining non-flag group cf. tf-idf vectors

Rank	Top ranking nodes in eigenvector centrality	Top ranking nodes in betweenness centrality
1.	**1664_CLAUBERG**, *Physica* (node 21)	**1757_De La CAILLE**, *Lectiones elementares astronomicae etc* (node 11)
2.	**1722_SERRURIER**, *Physicae Experimentis innixae tractatio* (node 2)	**1711_ANDALA**, *Syntagma theologico physico metaphysicum* (node 35)
3.	**1694_SPERLETTE**, *Physica nova* (node 31)	**1724_DeCROUSAZ**, *De physicae origine progressibus* (node 0)
4.	**1672_LeGRAND**, *Institutio philosophiae* (node 44)	
5.	**1748_MUSSCHENBROEK**, *Institutiones physicae* (node 23)	
6.	**1688_Geulincx**, *Physica vera* (node 37)	
7.	**1654_De RAEY**, *Clavis philosphiae naturalis* (node 16)	
8.	**1734_MUSSCHENBROEK**, *Elementa physicae* (node 19)	
9.	**1708_ANDALA**, *Exercitationes academicæ in philosophiam primam et naturalem* (node 26)	
10.	**1687_SCHWEITZER**, *Compendium physicae Aristotelico Cartesianae* (node 39)	

context, van Musschenbroek is the only Newtonian that emerges among the most central authors in the TM network.

Once again, we notice that only a small pool of works (illustrated in Table 11) operate as markers for delineating most of the others. These are not surprising authors, since they are also the same that show up consistently in our top rankings, suggesting that there is some direct correlation between the centrality of a work and its ability to mark a drift between different groups of other works.

If we now re-run our analysis described in stage 1 for the two updated groups, we can summarize the results in the following Table 12.

This summary Table 12 suggests that the refined Scholastic group is in fact dominated by French Scholastics of a Scotist orientation, as we surmised at stage 1. The non-Scholastic group seems now more clearly dominated by the presence of Cartesian works, although some Dutch Newtonians (such as Swinden) remain very central.

In a sense, these results corroborate the sorts of divides that we would expect based on the standard narrative about the evolution of early modern natural philosophy. For instance, the importance of the French Scotist school (and its influence on Descartes, among others) has been noticed by using more traditional methods (Ariew 2011, 71–100), but our approach provides an independent corroboration of it. This also shows that seemingly more original and eclectic works, like those of Jesuit authors (Rodrigo de Arriaga, for instance) do not seem to acquire a particular prominence in our representation. But given that we tackle *similarity* in this network, this might just confirm the fact that these authors are in fact much less standard and 'normal' than what

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Table 11. Authors and works that establish the largest number of strongest and weakest correlations in the non-Scholastic corpus

Authors	No. of strongest correlations TM	No. of weakest correlations TM	No. of strongest correlations tf-idf
1664_DESCARTES, *Le Monde*	22	0	0
1723_GRAVESAND, *Philosophiæ Newtonianaes institutiones*	7	5	1
1757_DeLaCAILLE, *Lectiones elementares astronomicae etc.*	4	10	1
1786_SWINDEN, *Positiones physicae*	1	9	0
1674_CALLY, *Institutio philosophiae*	0	12	1
1672_LeGRAND, *Institutio philosophiae*	0	0	7
1664_CLAUBERG, *Physica*	0	0	13
1748_MUSSCHENBROEK, *Institutiones physicae*	2	0	5

might be expected and, when considered from the structural point of view of the network we built, this translates in them being less central. In other words, our results can be interpreted as suggesting that while French Scotists contribute to sustaining a shared use of language in discussions concerning natural philosophy (especially among scholastics), Jesuits might be more eclectic, innovative, and original.[20]

4. Limitations

Before concluding, we would like to briefly comment on two relevant limitations concerning the method described.

The first and most obvious limitation concerns our initial choice of the corpus. We focused on Latin textbooks connected with only three geographical areas, namely, France, Britain, and the Dutch Republic. While surely important during the early modern period, this selection cannot claim to be exhaustive or representative of the broader landscape in which debates were unfolding. A larger corpus, the inclusion of authors and works from different areas, or even a greater variety of genres will arguably affect the results we obtained, although foreseeing exactly how would be speculative at this point. However, while this limitation has a direct impact on the interpretative claims we made concerning our results (which are directly dependent on the composition of the corpus), it has a much lesser impact on the workings of the method we presented, the illustration of which has been the main purpose of this paper. More generally, this sort of limitation is something inherent to any computational analysis and draws attention to the importance of sound methodological criteria and preliminary work in the selection and composition of the corpus to

[20]For a case study that might shed further light on this point, see Collacciani and Roux 2021. They show the complex interplay between Jesuit Scholastics and *novatores* in the teaching and rethinking of mathematical subjects by focusing on the theses defended at the *Collège de Clermont* from 1637 to 1682. Commenting on the Jesuit approach, they conclude: "The paradox of Jesuit science was indeed that it aimed at defending tradition—the uniformity and solidity of doctrine—, while placing itself at the forefront of the new sciences. [. . .] They did so to control the sciences according to the requirements of tradition." (p. 121).

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Table 12. Top centrality scores in the updated Scholastic and non-Scholastic groups

	TM Layer		TF-IDF Layer	
	Top-3 Eigen Centrality	Top-3 Betweenness Centrality	Top-3 Eigen Centrality	Top-3 Betweenness Centrality
Updated Scholastic Group	**1690_BOYVIN** *Philosophia Scoti* **1616_FABRI** *Philosophia naturalis* **1692_CAUVIN** *Cursus philometaphysicus*	**1669_COLUMBUS** *Novus cursus philosophicus Scotistarum Synopsis* **1727_ODÉ** *Principia philosophiae naturalis* **1690_BOYVIN** *Philosophia Scoti*	**1739_FRASSEN** *Philosophia academica* **1655_FOURNENC** *Universae philosophiae synopsis* **1647_STIER** *Praecepta doctrinae logicae*	**1832_JACQUIER** *Institutionum philosophicarum synopsis* **1660_CHABRON** *Philosophia per breviter argumenta explicata* **1622_BURGERSDIJK** *Idea philosophiae naturalis*
Updated non-Scholastic Group	**1664_DESCARTES** *Le Monde* **1644_DESCARTES** *Principia philosophiae* **1664_GREYDANUS** *Institutiones physicae*	**1757_DeLaCAILLE** *Lectiones elementares astronomicae etc* **1786_SWINDEN** *Positiones physicae* **1671_FABRI** *Physica*	**1664_CLAUBERG** *Physica* **1722_SERRURIER** *Physicae experimentis innixae tractatio* **1694_SPERLETTE** *Physica Nova*	**1762_DeLaCAILLE** *Ad lectiones elementares astronomiae etc* **1711_ANDALA** *Syntagma theologico physico metaphysicum* **1724_DeCROUSAZ** *De physicae origine progressibus*

which the computational tools will be applied. When historians decide to rely on the established canons for their contextual reconstructions, they can somehow dispense from this consideration, outsourcing it as it were to the canon itself. But as digital tools are used to move beyond the canonical barriers, this sort of consideration should become part of the ordinary routine of any computationally inflected research.

A second, more technical limitation concerns the degree to which our method can capture linguistic nuances and finer details. For instance, much of what discussed above relies on topic modelling, which basically extracts series of the most relevant keywords from texts based on their statistical occurrence. However, the same word can mean different things in different contexts, or when used by different authors. More simply, words can have synonyms that are not immediately captured by topic modelling, or be used in equivocal ways that should be distinguished. This seems even more important in a corpus such as the one presented here, in which many texts share a largely common background and technical vocabulary, and yet many of them present philosophically distinct and sometimes divergent views, which are sometimes very nuanced even for human readers to grasp.

There are two main approaches to addressing this limitation. The first consists in checking the most important results obtained by computational tools with close reading of (at least samples of) the texts. The second consists in combining multiple computational tools that can somehow compensate for the reciprocal limitations. To some extent, we already did so in combining topic modelling vectors with tf-idf vectors, which are more sensitive to the use of rarer and more idiosyncratic terms. Moreover, as we attempted to show in another study (Sangiacomo *et al.* 2022a), these tools can be further integrated with collocation analysis, which focuses precisely on the use of words in their immediate context and thus is fitted to distinguish between equivocal cases and possibly to detect synonyms or other variations in language usage (Garcia and García-Salido 2019). Nevertheless, close reading and the combination of multiple computational approaches are not alternative to one another; they simply expand the way in which traditional analysis and automated text mining complement each other.

5. Conclusions

In this paper, we demonstrated how an initial corpus of early modern texts can be represented as a network based on a text data vectorization method and then parsed in different groups, using both available information (including metadata) and computational approaches. These tools focus in particular on the way in which language is used in the works and hence it is, at best, indicative of potential philosophical or conceptual differences among them. As documented above, we have observed nonetheless that topic modelling in particular can provide a reliable basis on which to profile different groups of works and authors.

The results we obtained are consistent with our expectations (and this corroboration is important to assess whether the method we implemented is sound). Coming back to our two research questions, we can now establish (in answer to question 1) that the "Scholastic" group is relatively coherent and homogeneous, although it does allow for a number of authors that engage more critically with Scholastic sources and thus act as brokers or mediators in widening the scope of engagement with other sources. The "non-Scholastic" group is prima facie more heterogeneous, but after computational parsing, it shows two leading profiles: Cartesian and Newtonian.

If we consider now which authors would be most interesting to study (research question 2), our suggestion is that they should be those with highest centrality in general (Table 11), but also those that act as markers for delineating the various groups (Tables 9 and 12). As mentioned, centrality depends on the number and strength of correlations, but two works that are strongly correlated are not necessarily high in centrality. Hence, combining all the authors in these three tables allows us to cover two complementary perspectives on the network (correlation strength and centrality).

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The authors in Tables 9 and 12 are also particularly interesting because the ways in which they establish correlations with others highlight how distinct groups of authors and works can be identified within the corpus. Let us elaborate on this point.

From the point of view of network analysis, the strongest and weakest correlations among various works (such as those we studied) can be expected to indicate similarity and difference, especially when complemented with metadata about the nature of the works themselves (as we did by tagging certain works as "Scholastic"). What we did *not* expect was to observe that only a relatively small pool of works operated consistently as the most common markers for similarity strength across our corpus. This result might depend on the peculiar constitution of our corpus and it is only by replicating this research on an entirely different one that we might discern further elements to judge how consistent this feature might be. However, we also observe that most of the authors that serve as "markers" for different groups within the studied corpus also have significantly high centrality (like Descartes and 's Gravesande). By combining centrality and correlation strength, these authors are thus particularly significant for parsing the corpus in question. This raises a few more methodological reflections.

One more qualitative and established way of thinking about "central" authors in the history of philosophy and science is by considering them somehow "paradigmatic." This intuition is at the heart of Thomas Kuhn's well-known interpretation of "scientific revolutions" (Kuhn 1962). In its simplest form, a paradigm is a template for how to handle a certain puzzle or solve a certain problem. A paradigm, thus, provides an exemplary model for practitioners who are confronted with similar puzzles and problems by also allowing them to develop the paradigm further and extend its heuristic potential to other related cases. Developing paradigms can be considered the core business of what Kuhn called "normal science." Kuhn is perhaps most famous for his view about the discontinuous breaks between different periods in which older paradigms seem no longer viable and are replaced (in more or less radical ways) by new ones. However, these "revolutionary" discontinuities should not obscure the fact that, once the turmoil of challenging the established paradigms is over, science reverts to its normal form, which determines what most scientists do for most of the time (cf. Kuhn 1977). Early modern natural philosophy has been famously used as a case for the study of Kuhnian revolutions. In fact, the profound transformations that scholars have recognized in seventeenth- and eighteenth-century scientific practices became themselves a paradigm in history of science and philosophy for conceiving of "scientific revolutions." Much debate since the 1980s at least concerned whether early modern discontinuities are really so radical to deserve the label of "revolution" or not (Garber 2016).

However, we would like to resist the temptation of interpreting centrality measures as indicators of Kuhnian paradigms. Paradigms have at least two remarkable features: they tend to be chronologically *prior* to their further declensions and specifications, and they tend to be *normative* or prescriptive about what these further declensions should look like. Thinking about "normal science" in terms of paradigms thus amounts to searching for chains of variations within a continuous domain.

The works we singled out in Tables 9 and 12 are *not* paradigms. They are not chronologically *prior* with respect to many of the other works to which they are strongly correlated (especially in the case of the Scholastic works), and they are not necessarily or clearly *normative* (in Kuhn's sense) for other works either.[21] And yet, these works are consistently singled out from a computational view as encoding information about the relations of difference and similarity within the corpus. We suggest calling them "rifts"—to stress the idea that they constitute some sort of border within the corpus, which can be used to both separate different groups in terms of

[21]This does not mean that some of these works (like Descartes's *Le Monde*) cannot also play a paradigmatic function. Our point is simply is that in most cases this is far from obvious. For instance, we do have Newtonian works listed in Tables 9 and 12, but Newton himself does not figure there.

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similarity and difference, but also as a point of arrival of a certain crystallization in the use of language.

In our account, rifts have two features that make them different from paradigms: they tend to be chronologically *posterior* to the other works with which they most strongly correlate, and they tend to be *proscriptive*, in the sense that they rule out options (differences), without entailing more positive constraints. The textbooks by Senguerd or Le Grand arrive relatively late in the history of Scholastic of Cartesian philosophy, and yet they are indicative markers for all other works that operate broadly in the same context. However, these two textbooks do not positively determine what all Scholastic or Cartesian works should entail or discuss, or how, but simply show that departing significantly from what they do will lead to a drift away from Scholasticism or Cartesianism. In this sense, they operate in a similar way to geographical rifts between different territories.

The constitution of a philosophical canon can be understood as the search for the most paradigmatic works for a given period or field of study. Partially, this view lurks in the background of Kuhn's own account of paradigms, which makes it more explicit what a paradigm is and how it works in a given context. Hence, normal science is constructed in terms of manipulation of paradigms. Nevertheless, our method suggests an alternative account (perhaps compatible with the Kuhnian approach, but not reducible to it). Instead of looking just for paradigms, looking also for *rifts* can be effective for parsing a given corpus of works. By studying rift-works in more detail, one might gain a better understanding of how certain forms of discourse crystallized to such an extent that any further deviation would give rise to something different. This points to a fruitful way of enhancing the historian's ability to "get things right" when exploring philosophical ideas in their linguistic context.

Competing Interests Declaration. The authors declare none.

Acknolwedgements. This article is part of the project "The Normalization of Natural Philosophy" that has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme [grant number 801653].

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Appendix 1. Works parsed as 'scholastic' based on computational analysis

	Author and Title	Strongest and weakest correlations (TM)	Topic(s)	Strongest correlation (tf-idf)
1.	**1647_STIER**, *Praecepta doctrinae logicae*	**1690_BOYVIN**, *Philosophia Scoti* **1723_GRAVESAND**, *Philosophiæ Newtonianaes institutiones*	3w (40%) 5w (3%) 8w (53%)	**1739_FRASSEN**, *Philosophia academica*
2.	**1647_MAGNEN**, *Placita logicae*	**1631_BURGERSDIJK**, *Idea philosophiae* **1723_GRAVESAND**, *Philosophiæ Newtonianaes institutiones*	3w (29%) 5w (46%) 8w (23%)	**1672_LeGRAND**, *Institutio philosophiae*
3.	**1671_SCHEIBLER**, *Philosophia compendiosa*	**1690_BOYVIN**, *Philosophia Scoti* **1649_BASSON**, *Philosophiae naturalis adversus Aristotelem libri XII*	2w (19%) 3w (19%) 8w (44%)	**1664_GREYDANUS**, *Institutiones physicae*
4.	**1671_SANDERSON**, *Physicae scientiae compendium*	**1646_REGIUS**, *Fundamenta physices* **1723_GRAVESAND**, *Philosophiæ Newtonianaes institutiones*	3w (65%) 8w (34%)	**1647_STIER**, *Praecepta doctrinae logicae*
5.	**1672_SANDERSON**, *Logicae et physicae artis compendium*	**1690_BOYVIN**, *Philosophia Scoti* **1723_GRAVESAND**, *Philosophiæ Newtonianaes institutiones*	5w (16%) 8w (78%)	**1670_GOUDIN**, *Philosophia iuxta inconcussa*
6.	**1676_PITCARNE**, *Compendiaria et perfacilis physiologiae idea*		3w (43%) 8w (47%)	**1739_FRASSEN**, *Philosophia academica*
7.	**1699_LINGEN**, *Medulla tripartita philosophiae veteris*		3w (15%) 8w (84%)	
8.	**1705_LINGEN**, *Cursus philosophicus*		3w (16%) 8w (83%)	
9.	**1656_HOBBES**, *Elementa philosophiae*	**1690_BOYVIN**, *Philosophia Scoti* **1631_BURGERSDIJK** *Idea philosophiae*	2w (8%) 3w (26%) 8w (63%)	**1664_CLAUBERG**, *Physica*
10.	**1587_ABRAHAM**, *Methodicae institutiones*	**1631_BURGERSDIJK**, *Idea philosophiae* **1723_GRAVESAND**, *Philosophiæ Newtonianaes institutiones*	5w (82%) 8w (17%)	**1619_CRASSOT**, *Totius philosophiae peripateticae*
11.	**1623_BACON**, *De Augmentis Scientiarum*		3w (4%) 5w (95%)	
12.	**1620_BACON**, *Instauratio magna*	**1631_BURGERSDIJK**, *Idea philosophiae* **1692_CAUVIN**, *Cursus philometaphysicus*	3w (17%) 5w (81%)	**1672_LeGRAND**, *Institutio philosophiae*
13.	**1620_BACON**, *Novum organum scientiarum*		3w (17%) 5w (82%)	
14.	**1711_POURCHOT**, *Institutiones philosophicae_Vol1*	**1690_BOYVIN**, *Philosophia Scoti* **1723_GRAVESAND**, *Philosophiæ Newtonianaes institutiones*	3w (14%) 5w (14%) 8w (70%)	**1695_CALLY**, *Universae philosophiae institutio*

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(*Continued*)

	Author and Title	Strongest and weakest correlations (TM)	Topic(s)	Strongest correlation (tf-idf)
15.	**1733_POURCHOT**, *Institutiones philosophicae_Vol2*	**1646_REGIUS**, *Fundamenta physices* **1587_ABRAHAM**, *Methodicae institutiones*	3w (14%) 5w (14%) 8w (70%)	**1694_SPERLETTE**, *Physica nova*
16.	**1751_POURCHOT**, *Institutiones philosophicae_Vol3*	**1646_REGIUS**, *Fundamenta physices* **1619_CRASSOT**, *Totius philosophiae peripateticae corpus*	3w (99%)	
17.	**1715_POURCHOT**, *Institutiones philosophicae_Vol4*	**1587_ABRAHAM**, *Methodicae institutiones* **1723_GRAVESAND**, *Philosophiæ Newtonianaes institutiones*	5w (77%) 8w (20%)	**669_MELLES**, *Novum totius philosophiae syntagma*
18.	**1722_CLERC**. *Opera philosophica Vol 1*	**1631_BURGERSDIJK**, *Idea philosophiae* **1723_GRAVESAND**, *Philosophiæ Newtonianaes institutiones*	3w (25%) 5w (47%) 8w (26%)	**1711_POURCHOT**, *Institutiones philosophicae Vol 1*
19.	**1722_CLERC**, *Opera philosophica Vol 2*		3w (29%) 5w (67%) 8w (3%)	**1672_LeGRAND**, *Institutio philosophiae*
20.	**1722_CLERC**, *Opera philosophica Vol 3*	**1646_REGIUS**, *Fundamenta physices* **1619_CRASSOT**, *Totius philosophiae peripateticae corpus*	3w (99%)	**1681_DuHAMEL**, *Philosophia vetus et nova Vol 5*
21.	**1722_CLERC**, *Opera philosophica Vol 4*		2w (24%) 8w (75%)	**1726_MUSSCHENBROEK** *Epitome elementorum physico mathematicorum*
22.	**1832_JACQUIER**, *Institutionum philosophicarum synopsis*	**1587_ABRAHAM**, *Methodicae institutiones* **1723_GRAVESAND**, *Philosophiæ Newtonianaes institutiones*	3w (8%) 5w (75%) 8w (23%)	**669_MELLES**, *Novum totius philosophiae syntagma*

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Appendix 2. Computationally updated non-scholastic group (cf. topics and tf-idf vectors)

		Most and least connected nodes cf. topic vectors	Most connected node cf. tf-idf
1.	**1644_DESCARTES**, *Principia philosophiae*	**1664_GREYDANUS**, *Institutiones physicae* **1723_GRAVESAND**, *Philosophiæ Newtonianaes institutiones*	**1664_CLAUBERG**, *Physica*
2.	**1664_DESCARTES**, *Le Monde*		**1672_LeGRAND**, *Institutio philosophiae*
3.	**1664_GREYDANUS**, *Institutiones physicae*	**1664_DESCARTES**, *Le Monde* **1723_GRAVESAND**, *Philosophiæ Newtonianaes institutiones*	**1646_REGIUS**, *Fundamenta physices*
4.	**1651_HOLWARDA**, *Philosophia naturalis*		**1722_SERRURIER**, *Physicae experimentis innixae tractatio*
5.	**1664_CLAUBERG**, *Physica*		**1672_LeGRAND**, *Institutio philosophiae*
6.	**1746_DAGOUMER**, *Philosophia ad usum scholae*		**1694_SPERLETTE**, *Physica nova*
7.	**1724_DeCROUSAZ** *De physicae origine progressibus*		**1664_CLAUBERG**, *Physica*
8.	**1671_FABRI** *Physica*	**1648_NOEL**, *Physica vetus et nova* **1757_de la CAILLE**, *Lectiones elementares astronomicae etc.*	**1651_HOLWARDA**, *Philosophia naturalis*
9.	**1672_LeGRAND**, *Institutio philosophiae*	**1687_SCHWEITZER**, *Compendium physicae Aristotelico Cartesianae* **1757_de la CAILLE**, *Lectiones elementares astronomicae etc*	**1664_CLAUBERG**, *Physica*
10.	**1623_ESPAGNET**, *Enchiridion physicae restitutae*	**1711_ANDALA**, *Syntagma theologico physico metaphysicum* **1757_de la CAILLE**, *Lectiones elementares astronomicae etc*	**1672_LeGRAND**, *Institutio philosophiae*
11.	**1646_REGIUS**, *Fundamenta physices*	**1664_DESCARTES**, *Le Monde* **1757_DeLaCAILLE**, *Lectiones elementares astronomicae etc*	**1664_CLAUBERG**, Physica
12.	**1678_DuHAMEL**, *Philosophia vetus et nova* Vol 4		**1695_LeCLERC**, *Physica sive de rebus corporeis*
13.	**1694_SPERLETTE**, *Physica nova*		**1664_CLAUBERG**, *Physica*
14.	**1695_LeCLERC**, *Physica sive de rebus corporeis*		**1672_Le GRAND**, *Institutio philosophiae*

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		Most and least connected nodes cf. topic vectors	Most connected node cf. tf-idf
15.	**1700_BAYLE**, *Institutiones physicae*		**1664_CLAUBERG**, *Physica*
16.	**1783_ParaDuPHANJAS**, *Theoria de entium sensiblium sive physica*		**1748_MUSSCHENBROEK**, *Institutiones physicae*
17.	**1681_DuHAMEL**, *Philosophia vetus et nova* Vol 5	**1664_DESCARTES**, *Le Monde* **1674_CALLY**, *Institutio philosophiae*	**1695_LeCLERC**, *Physica sive de rebus corporeis*
18.	**1686_DALRYMPLE**, *Physiologia nova experimentalis*		**1722_SERRURIER**, *Physicae experimentis innixae tractatio*
19.	**1722_SERRURIER**, *Physicae experimentis innixae tractatio*		**1664_CLAUBERG**, *Physica*
20.	**1654_DeRAEY**, *Clavis philosphiae naturalis*	**1664_DESCARTES**, *Le Monde* **1786_SWINDEN**, *Positiones physicae*	
21.	**1688_GEULINCX**, *Compendium physicae*		
22.	**1688_GEULINCX**, *Physica vera*		
23.	**1688_LANGENHERT**, *Compendium physicae*		
24.	**1687_SCHWEITZER**, *Compendium physicae Aristotelico Cartesianae*		
25.	**1708_ANDALA**, *Exercitationes academicæ in philosophiam primam et naturalem*		
26.	**1648_NOEL**, *Physica vetus et nova*		**1694_SPERLETTE**, *Physica nova*
27.	**1732_ENGELHARD**, *Institutionum philosophiae theoreticae tomus*	**1664_DESCARTES**, *Le Monde* **1671_FABRI**, *Physica*	**1708_ANDALA**, *Exercitationes academicæ in philosophiam primam et naturalem*
28.	**1641_BOOTIUS**, *Philosophia naturalis reformata*	**1786_SWINDEN**, *Positiones physicae* **1757_De la CAILLE**, *Lectiones elementares astronomicae etc.*	**1672_Le GRAND**, *Institutio philosophiae*
29.	**1674_CALLY**, *Institutio philosophiae*	**1694_SPERLETTE**, *Physica nova* **1671_FABRI**, *Physica*	

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		Most and least connected nodes cf. topic vectors	Most connected node cf. tf-idf
30.	**1695_CALLY**, *Universae philosophiae institutio*	**1694_SPERLETTE**, *Physica nova* **1786_SWINDEN**, *Positiones physicae*	
31.	**1711_ANDALA**, *Syntagma theologico physico metaphysicum*	**1623_ESPAGNET**, *Enchiridion physicae restitutae* **1786_SWINDEN**, *Positiones physicae*	**1695_CALLY**, *Universae philosophiae institutio*
32.	**1723_GRAVESANDE**, *Philosophiæ Newtonianaes institutiones*	**1734_MUSSCHENBROEK**, *Elementa physicae* **1695_CALLY**, *Universae philosophiae institutio*	**1748_MUSSCHENBROEK**, *Institutiones physicae*
33.	**1720_GRAVESANDE**, Physices Elementa Mathematica		**1762_MUSSCHENBROEK**, *Compendium physicae experimentalis*
34.	**1726_MUSSCHENBROEK**, *Epitome elementorum physico mathematicorum*	**1723_GRAVESAND**, *Philosophiæ Newtonianaes institutiones* **1674_CALLY**, *Institutio philosophiae*	**1734_MUSSCHENBROEK**, *Elementa physicae*
35.	**1734_MUSSCHENBROEK**, *Elementa physicae*		**1723_GRAVESAND** *Philosophiæ Newtonianaes institutiones*
36.	**1762_MUSSCHENBROEK**, *Compendium physicae experimentalis*		**1722_SERRURIER**, *Physicae experimentis innixae tractatio*
37.	**1748_MUSSCHENBROEK**, *Institutiones physicae*		
38.	**1757_DeLaCAILLE**, *Lectiones elementares astronomicae etc.*	**1702_GREGORY**, *Astronomiae physicae et geometricae elementa* **1671_FABRI**, *Physica*	**1702_GREGORY**, *Astronomiae physicae et geometricae elementa*
39.	**1762_DeLaCAILLE**, *Ad lectiones elementares astronomiae etc.*		
40.	**1687_NEWTON**, *Philosophiae naturalis principia matematica*	**1757_DeLaCAILLE**, *Lectiones elementares astronomicae etc.* **1671_FABRI**, *Physica*	**1701_KEILL**, *Introductio ad veram physicam*
41.	**1702_GREGORY**, AstronomiaePhysicaeEtGeometricaeElementa		**1757_DeLaCAILLE**, *Lectiones elementares astronomicae etc.*
42.	**1701_KEILL**, *Introductio ad veram physicam*	**1757_DeLaCAILLE**, *Lectiones elementares astronomicae etc.* **1674_CALLY**, *Institutio philosophiae*	**1687_NEWTON**, *Philosophiae naturalis principia matematica*
43.	**1783_SEGUY**, *Philosophia ad usum scholarum accommodata*	**1757_DeLaCAILLE**, *Lectiones elementares astronomicae etc.* **1671_FABRI**, *Physica*	**1701_KEILL**, *Introductio ad veram physicam*

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		Most and least connected nodes cf. topic vectors	Most connected node cf. tf-idf
44.	**1786_SWINDEN**, *Positiones physicae*	**1641_BOOTIUS**, *Philosophia naturalis reformata* **1695_CALLY**, *Universae Philosophiae institutio*	**1800_VanDerEYCK**, *Institutiones physicae*
45.	**1800_VanDerEYCK**, *Institutiones physicae*	**1723_GRAVESAND**, *Philosophiæ Newtonianaes institutiones* **1674_CALLY**, *Institutio philosophiae*	**1748_MUSSCHENBROEK**, *Institutiones physicae*

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Cite this article: Sangiacomo, Andrea and Raluca Tanasescu. 2025. "Computational Rifts: Parsing the Context of Early Modern Natural Philosophy," *Science in Context*. doi:10.1017/S0269889725100653