

CHAPTER 14

The Many Ways to Talk about the Transits of Venus

Astronomical Discourses in *Philosophical Transactions*, 1753–1777

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A Popular Astronomical Event

In the 1760s, one of astronomy's rarest predictable phenomena, the so-called Transit of Venus, was calculated to take place twice: in 1761 and in 1769. This phenomenon, when the planet Venus passes across the Sun, from the Earth's vantage point, was not only extremely rare, as the previous transit had taken place in 1639 and the next was to follow in 1874, but also very valuable scientifically, as observing this kind of transit would make it possible to determine the distance between the Earth and the Sun more accurately than before. This could in turn make it easier to improve a number of practical issues relying on astronomical knowledge, foremost among them to improve the accuracy of calculating locations at sea, which at this time was at best inaccurate, often resulting in costly and deadly accidents. Thus, the two Transit of Venus events and the astronomical information that could be derived from observing them enjoyed wide interest among both scientific professionals and the general

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public. The scientific interest in the transits during the 18th century was represented through a large number of news items and scientific reports in the scientific literature, especially in scientific periodicals, such as the *Philosophical Transactions of the Royal Society of London*. In short, there was a large and varied scientific discourse talking about the Transits of Venus. This chapter explores what new historical knowledge about science in the 18th century we can derive from using digital methods to study such scientific discourse related to a particular scientific phenomenon.

However, alongside the natural philosophical news and reports, many broader perspectives towards early modern knowledge and the early modern world itself were also communicated in the scientific journals. By using digital history methodologies to analyse the qualitative meanings and quantitative amounts of the common topics and themes in a scientific periodical, I suggest in this chapter that there were simultaneously nine different ways of talking, or discourses, about astronomy and the two Transits of Venus of the 1760s.

Astronomy has been one of the main ways for scientists to explore explanations about our place in the universe, but astronomical knowledge has also been used for other more practical applications in economy, politics and transportation. This combination of pursuing natural philosophy endeavours both for knowledge and for practical applications was also central for the Royal Society of London, established in 1660 in England for improving the knowledge of nature and mankind, as articulated in their full official name. To serve astronomical practice, the Society funded two large expeditions to make observations of the 1760s Transits of Venus, but at the same time and partly through these expeditions they also took part in the larger and wider transformation of how the natural sciences were understood in the 17th and 18th centuries, by creating a communal and public space for circulating the new knowledge. The Society circulated a newsletter that disseminated and shared the new scientific information coming from collecting and observing abroad on scientific voyages and commercial encounters, as well as through experiments at home. The letter soon turned into the form of a periodical, entitled *Philosophical Transactions Giving some Account of the present Undertakings, Studies, and Labours of the Ingenious in many considerable parts of the World*, established in 1665 and published as the Society's official journal from 1752. From the mid-18th century onwards, *Philosophical Transactions* was a journal publishing scientific correspondence that had been selected and reviewed by the fellows of the Society. The journal also had a much wider readership than just natural philosophers.¹ Its topics included news about the latest innovations and discoveries and reports on geography, natural scientific specimens and natural and man-made phenomena, such as weather and electricity. Even the work of amateur experimenters was published, whereas many professional reports sent to the Royal Society were rejected and put to one side with a note 'not to be printed'.²

In the mid-1700s, many nations participated in a race for the knowledge, prestige and power that could be gained through successful observations of the two

predicted Transits of Venus. National and international networks of knowledge invested a significant amount in astronomy research, and the importance of succeeding in observing the Transits of Venus has often been compared to the Cold War space race of the 20th century. Central in this were the observation instruments which were carefully collected and arranged for transportation to judiciously planned observation locations.³ The Transits of Venus were then widely discussed in various contemporary printed periodicals, as well as in the general press. It was understandably a prominent topic in periodicals such as *Philosophical Transactions* reporting on the latest news within natural philosophy. The emphasis was on the conducted experiments and the reporting and theorising of the events. However, at the same time, the Royal Society's public communications also conveyed other more elusive and implied perspectives on the philosophical inquiries to their wide group of readers. In this light, this chapter uses the reporting of the Transits of Venus in *Philosophical Transactions* to critically discuss what kind of view of 'scientific' inquiry was offered to its readers: What was actually discussed about astronomy in particular and the new science in general among the texts that succeeded in being printed in *Philosophical Transactions* during the late 18th century? The guiding hypotheses behind the study is that the general values of 18th-century British society and the philosophical environment have been repeated directly and indirectly in the texts. By re-reading this discourse with the digital methods, we can access the underlying thoughts, paradigms (such as a shared model of the universe) and practices related to experimental science that existed at this time.

Topic Modelling the Publication of New Science

The historical meanings of the editing and peer reviews of *Philosophical Transactions* has been studied by Ellen Valle in particular, and subsequently by Julie McDougall-Waters, Noah Moxham and Aileen Fyfe.⁴ My research continues their work by applying the use of 'machine reading' and the method of topic modelling for finding the underlying patterns and values that have influenced the public writing about new scientific knowledge. By comparing statistical amounts of various topics in *Philosophical Transactions* at different times, topic modelling reveals temporal changes in scientific approaches in the many ways of talking about the process and of the degrees of certainty within the emergent sciences. This could be a major contribution to the history of early scientific communications because this kind of temporal change has not been discussed in the earlier scholarship, which has only applied manual reading of these resources. The digital methodology of topic modelling provided a way to examine the large amount of texts in *Philosophical Transactions* and to reveal the changing patterns in the ways in which the two transits were discussed. It located the internal relations inside the 'big data', comprising all the words in the texts, and teased out their shared and underlying meanings.

I have focused on 1753–1777 as a period of 25 years containing the important astronomical events (the two Transits of Venus in 1761 and 1769). This period also covers the time after the Society had formally taken over the journal in 1752 and begun editing the articles communally via the so-called Committee of Papers, and before it changed into a new period of knowledge circulation in 1778 when Joseph Banks took on the presidency of the Royal Society. The time frame also contains the collection of new data during world-changing voyages of exploration, such as those of Captain Wallis in 1765–1768 and Captain Cook in 1768–1780, both supervised by the Royal Society.

The selected corpus of texts from *Philosophical Transactions* consists of a set of 1,421 documents relating to the transits, which represents a collective public discourse on scientific discoveries, innovations and experimental routine (a typical genre of texts published in the journal). The texts of the corpus were generated by optical character recognition (OCR) of a digitised version of *Philosophical Transactions* provided for research purposes by JStor, and I used a temporal selection of the *Royal Society Corpus*⁵ which had been collected and pre-processed in a previous linguistics project headed by Elke Teich.⁶ Their pre-processing included the transformation of data into a standardised format, cleaning of data (for example, OCR errors) and derivation and annotation of metadata.⁷

The research process consisted of three stages, which combined statistical and computational quantitative methods with qualitative analysis of the texts. During the first stage, I applied topic modelling to the corpus to create lists of probable keywords describing the themes existing within the data corpus. To operate with the topic modelling algorithm, I prepared a so-called ‘stop list’ of very common words (such as *the*, *is*, *as*, etc., as well as prepositions and conjunctions) to be filtered out and excluded in the analysis of the corpus. I also arranged the processing of the corpus temporally by dividing it into five-year sets (1753–1757, 1758–1762, 1763–1767, 1768–1772, 1773–1777) and then ran these through the topic modelling algorithm implemented in the MALLET software application. The output was a list of various topics or themes of interconnected keywords co-occurring throughout the articles. As a preliminary analysis, I used MALLET to produce a varying number of topics from the corpus and concluded that the best and most realistic fit, in terms of what from the keywords appeared to be relevant and meaningful topics that were not too general or too narrow, was when the number of topics was 50. Following this, I grouped the topics along semantic similarities in their keywords in order to locate their relations to the scientific contexts in which the original texts of the corpus were created. This was a crucial part of the research; while a ‘topic’ to the computer is merely a list of words that occur together in statistically meaningful ways,⁸ in the following manual analyses by the researcher these lists are shown as a semantically meaningful string of keywords which need to be sewn together with a larger thread of historical context and interpreted in order to provide a meaningful label that refers back to the historical context. Therefore,

the historical work of contextualising the English 1700s science discourse was ongoing throughout the entire research process.

In summary of the above, I programmed MALLET to create a list of 50 topics, each consisting of 20 keywords, and entered these into a spreadsheet which showed the number of these topics during the chosen years. The keywords represent co-occurrence patterns in the data corpus and probabilistic appearances of a particular theme. I located keywords that signified general trends and particular themes, such as those that concerned instruments in observation and experiments. After examining and labelling all the topics which were present in 2% or more of the text mass, I grouped the topics according to their semantic similarities. This revealed that the common topics in the data could be roughly grouped according to 'polite correspondence style', 'astronomy', 'chemistry', 'weather' and 'instruments and their use'. In actual fact, it was not until this stage that the processing of the data highlighted the most fruitful research questions warranting further investigation.

As mentioned above, Teich's linguistics team had already carried out research that applied topic modelling to the first two centuries of *Philosophical Transactions*. Their visualisations enable us to see topical trends in the corpus, in particular in terms of discipline formation and specialisation, that there is a growing separation of individual scientific disciplines over time and that the discourse became increasingly specific over time.⁹ Aiming at different perspectives on the proposed material and research questions, I thus designed the commands and continued to fine-tune my topic modelling less towards general themes stretching over large time periods, and more towards more specific themes connected to my more focused period and scientific developments. As a result, this is an example not only of applying a fresh perspective on an already known resource, but, importantly, also of a collaboration among experts which is characteristic for contemporary digital humanities.¹⁰ Teich's team identified 24 different topics in *Philosophical Transactions* which indicated the development of scientific sub-disciplines (including Chemistry, Mechanics and Reproduction, among others). This research was an excellent starting point for my inquiries, in which I used an alternative approach to examine the periodical and which found 25 topics that were theoretically visible, as they each referred to more than 1% of the amount of text. Our two approaches to the same data differ in the close reading perspectives, and the comparison has led me to notice other wider perspectives. In the following section, I will problematise what else can be depicted from the results of a computer-assisted distant reading of the periodical from the perspective of the cultural history of science.

Thematic Trends of the Discussion

When beginning to discuss the quantitative results of the topic modelling, it is indeed no surprise that the keywords and their frequencies show a nota-

ble rise in astronomical topics around both transits. They are visible during most years as a relatively large number of texts on astronomy, with the text mining revealing keywords such as 'transit', 'June' and 'Venus', where 'June' was the month when the 1761 transit occurred. Astronomy and its related practices and techniques were commonly mentioned, but in the researched time span, *Philosophical Transactions* also discussed a few non-astronomical topics. However, these also helped to locate relevant aspects of the scientific ways of talking also within astronomy, as I will demonstrate below when discussing the case of systematising observation results. In particular, these non-astronomical topics have a specific value as they can vividly illuminate what is *not* part of other discussions.

Shared discourses, split viewpoints

The remainder of this chapter will analyse the astronomical ways of talking by contextualising and connecting the prevalent topics in the published scientific communications (for example, in *Philosophical Transactions*) to the making of early modern knowledge. I begin with a thematic analysis of the text-mining results and then conclude with a summary of the approaches and temporal appearances of the nine ways of talking about science. Keywords of all of the discussed topics are listed in Appendix 14.1.¹¹

The data shows that the discourse on the first transit (1761) circulated around various viewpoints concerning reliability and the structure of the solar system. The common themes consisted of exactness, measuring, relating and belonging (to the universe), which also reflect the excitement of using the enthusiastically approved, state-of-the-art instruments in making observations of the first transit. Instead of describing causal chains, the observations were communicated as indicating the values of various connecting sets of rules and theories. The observations were thus not neutral, but became charged with rules and theories.

The lists of observation data were apparently published as they had been recorded, and were then consequently explained through the use of mathematical algebraic reasoning (the topic 'Astronomical distance' with 11%), as a system of heavens that could be revealed ('Rules of the stars' topic with 5%) and how it related to the solar system ('Appliances' topic with 8%).¹² The first two topics were only present in 1758–1762, while 'Solar system' was an ongoing topic, although notably only at the beginning, as it almost disappeared (1% to 2%) around the second transit. In 1763–1767, the theme seems to split into two topics, as a similar topic 'Heavenly bodies' shortly appears at this point. However, it differs somewhat, as this topic focuses on the planetary system and its parts (which are described in a similar manner as the reports would talk about the human body, possibly in a 'plain' style), while the topic 'Solar system' discusses what can be achieved on Earth by using those heavenly bodies:

for example, *'latitude'* and *'degree'* are among its keywords, which could often signify the calculation of the location at sea. These distinctions already show that the discourse on the transits addressed many separate views on the topic, varying talk which not only promoted causal theories and mathematical reasoning or arranging raw data *'plainly'*, but also offered discussions on more social factors, such as the extent of trust and belief that could be placed in astronomical calculations.

There might be some skewing of this topic, as a large number of its keywords might be brought about by one single lengthy paper (23 pages in print) in *Philosophical Transactions* by the Astronomer Royal Nevil Maskelyne, on observations and methodological rules he developed following the 1761 transit. By collecting and comparing the data received from various observations at St. Helena about the Transit of Venus, Maskelyne formulated a set of theoretical rules about the skies and the use of astronomical instruments.¹³ During this time, if the transaction discourse is representative, apparently a rather small part (*'Rules of the stars'* topic with 5%) of the astronomical interest concerned astronomy's theoretical system. This theoretical discourse topic also existed at the time of the second transit in 1769, meaning that Maskelyne's ideas continued to be referred to or discussed after his paper's initial 1761 publication. However, as the topic decreased from 5% to 2%, this indicates an increasing emphasis on other perspectives, such as a dispute on the relative importance of causal versus mathematical evidence. That Maskelyne's article constituted a dominant part of the topic could easily be identified through a keyword search in the dataset, and it is worth emphasising that it is both important as well as useful to also apply close reading to enable closer study and control the content of themes that arise from the distant reading of the text-mining results.

One alternative to using theories and mathematics to explain astronomical measurements was through empirical means (namely, repeated experiments or observations). This is demonstrated by the topic *'Distance measuring process'* being continuously very strong (9–12%) throughout the period, thus representing scientists' interest in the general process of experimentation, while the keywords of the *'Astronomical distance'* topic point towards explanations and mechanisms based on the laws of physics, physical circumstances and entities, such as velocity and distance. Apart from *'glass'* (a reference to a material most likely indicating the lens of a telescope or an experiment tube), the keywords of the *'Distance measurement process'* topic (*'distance'*, *'degrees'*, *'line'* and *'places'*) primarily point towards intangible concepts connected to very tangible experiments, of measuring and of practically producing new observational data. Interestingly, its keywords of *'appearance'*, *'means'* and *'method'* give this discussion various kinds of unsure, unsettled and dynamic connotations and, furthermore, the topic contained discussions about particular location-specific, probable or *'apparent'* aspects.

The topic *'Astronomical distance'* was discussed only once, in the 1758–1762 segment, with a sudden 11% spike, in which the observations of the heavens

(and the astronomical signified keywords of [moon/sun's] limb, sun, star and wheel) were linked with the data in the tables (measure, feet, foot, inches) and algebra (cos, distance, wheel). This and the 'Distance measurement experiments' topic both mention the word 'distance', but the other keywords indicate a clear difference in meaning between the two, as the topics reveal how 'distance' was to be observed, depending on whether it addressed celestial distances or distances on Earth. In comparing these two topics, I claim that the topic modelling algorithm has revealed a very important temporal change: it has located a mainly shared discourse about the practices of deciding on the distance, but it has split this theme into two. Their separate keyword lists initially differ between practical experimentalism and understanding the physical theories of the phenomena, but after this, both topics also share similar passages about the use of instruments and theorising the measurements.¹⁴ Both topics discuss various means to measure distance, and the shared keywords of *measure*, *distance* and [the method of heaven's] *wheel*, which all appear in both of the discussed topics, capture a broader, shared discussion. This is the value of topic modelling: by using machine-reading and locating shared but slightly variable topics, the nuances of the discussions can better come to light.

The examination of these topics indicates that there were two profoundly different ways of what was considered to be the reliable way to find data. The first transit in particular allowed plenty of interest (11%) in making arguments through calculations, but for the second transit the frequencies indicate that the mathematics were no longer a primary worry. There is only a short temporal change within the statistics that could, however, exemplify a dramatic change in the paradigm. It appears that a more general perspective about measurements was developing and that means other than mathematical results had become increasingly relevant in the early modern search for reliability and 'truth'.

Following Newton's formulation of mathematical laws of nature, in the 18th century it was usually considered sufficient to settle an astronomical dispute if one could arrive at a successful set of mathematical calculations.¹⁵ At a time when logical causalities became less interesting to the scientists, the large number of words indicating probability in my data raises questions about reliability, the meanings of eye-witnessing and the capabilities of the human mind and senses. These topics can also indicate that there was a split discourse according to the two schools of realists: one consisting of mathematical realists, including those who thought mathematics could provide the real motions of celestial bodies; the other comprising the group of physical realists who held that a mathematical model of the real structure of the heavens should be based on physics.¹⁶

Another example of transitions within the paradigm can be noted in the texts written in Latin. A few data and observation reports were received and published in Latin, including the transit observations from Uppsala in Sweden.¹⁷ However, this kind of discourse was narrow and concentrated into two topics: 'Solar system Latin' and 'Transit and Latin'. The two topics were both most

popular around the first transit, and while they both circulated the calculations for longitude, they differed in their perspectives. The first described the observations plainly, while the other seems to have emphasised the materiality of the observation process. This means that in Latin there were at the time in question two ways of discussing astronomy: first, as descriptions of the solar system; and, second, in the form of the actual process of making observations of the solar system. It also appears that during this period both Latin topics started to disappear. This decline of Latin had also been noted in passing by the previously mentioned linguistics researchers when stating that some non-thematic topics, including texts written in Latin, reached their peak in the early 18th century.¹⁸ However, as we can observe in the keyword list, Latin was still used in the late 18th century in publishing accounts concerning the heavens and the solar system. The topic 'Solar system Latin' was popular between 1758 and 1767, with a 6% to 8% share of all discussions, but then almost disappeared (1% to 2% in the subsequent decade), while the 'Transit and Latin' topic was visible throughout the entire transit decade, but only with a 2% to 5% share.

The host of Latin words in 'Transit and Latin', *'vero'*, *'inter'*, *'hoc'*, *'enim'* and *'hujus'*, are all abstract, frequent words. *'Vero'* is the fascinating one, as it means 'truly, indeed, to be sure, certainly'. In fact, among the 500 keywords in the other topics, there are many that indicate a continuous interest towards the 'true', such as in addition to 'true', also 'purpose', 'order', 'error', 'anemones', 'effect', 'probability' and 'rules'. And deriving from the keywords 'apparent' and 'error', the 'Telescope observations' topic can be seen as promoting an openness towards the meanings of the results and how changing circumstances could affect the observations, although the task in question seemed to be regarding some precise measurements, including 'minutes' and 'seconds'.

Taken together, these topics discuss a contemporary science culture that was seen as being open-ended and constantly recreated by various actors.¹⁹ In particular, the certainty of probabilities and the transparency about practical choices when making observations seem to be continuing themes in the various discourses.

Talking about the weather

The external conditions of the observations were and are a central issue to astronomers. It especially appears to be the main way to talk about the astronomical observations in one topic which, due to its huge number of weather keywords, has been labelled 'Astronomer's weather'. This was a strong topic during its time: although it only existed during the 1768–1772 period, the topic arrived with a notable 14% of the volume of text published in *Philosophical Transactions*. The first words in this topic are 'ditto', 'air' and 'limb [of the moon or the sun]' which apparently refer to astronomical observation tables. These keywords were also accompanied by 'June' and by as many as five words describing weather.

Throughout the years in question, the weather was continuously discussed, but there is some increase in the latter 10 years of the studied period, during which the second Transit of Venus took place. This sudden rise in the topic modelling chart is understandable in the light of the unfortunate event of not having been able to make successful observations of the transit on the first attempt in 1761 due to difficult weather. It is therefore no surprise that we can find some discussion about the conditions already before and after the 1761 transit: it was anticipated that clouds could obscure visibility at the vital moment, as they had so often done when Edmond Halley had been observing a similar transit almost a century earlier.²⁰ The unpredictability of weather was just one of the several reasons why there was a need to simultaneously observe the Transit of Venus from many different and varied places on Earth. Beside cloud cover, Halley had already in 1716 pointed out in his observation advice the importance of arranging coverage from northern and southern latitudes, as both the ingress and the egress could not be observed from all the locations. Thus, to avoid a similar fate, a large-scale operation was connected to the Transits of Venus in order to coordinate several international observations and, as had been suggested by Halley, to arrange multiple observatory tents to be set up around the globe by British, Austrian and French observers.²¹ The more observations that were made from many different and widely separated vantage points, the more accurate the ultimate results were likely to be.²²

Weather was also employed in other discourses. In the topics 'Environmental circumstances' and 'Travel narrative', weather figures in the form of the blame and complaints that often figured in early modern observation accounts. These often served very practical purposes, as a failure to conduct an experiment could often be more easily accepted due to bad weather. Simultaneously, these topics address the practice and materiality of the observation process in the form of broken instruments, successful delivery of the instruments and other aspects affected by bad weather. In this, the topics provide valuable tangible insights into early modern scientific practice.

The topics concerning the weather were used in particular around the second transit (1769). The topic 'Telescope observations' appears to mention the weather during both transits, but only moderately, with a few percent (2% to 4% during the 1758–1772 period), while the main emphasis is on discussing the way in which the new more advanced instruments could create or diminish the observation errors. Nevil Maskelyne wrote a letter to the Royal Society in 1761 which discussed at length various contextual influences on the use of the instruments. Before listing the transit observation results, Maskelyne wrote about 'the observations themselves, and mention[ed] some cautions concerning them',²³ which among others included the exact practical adjustment of the quadrant (a navigational instrument used for angle measurements).^{24,25} The context in which the instruments were used, then, was important to the narrative and the manner in which they were discussed.

On the other hand, the failure to produce consistent and certain results during the scientific voyages of observation connected to the 1760s transits has been blamed not just on bad weather, but also on other external or material conditions that affected the voyage, such as war, illness and, above all, inexperience in observing the phenomenon in question.²⁶ The quantitative distant reading of results through topic modelling provides a new opportunity to investigate how strong the pattern has been to make arguments about the failure (and at times success) of experiments through referring to external circumstances. Such talk about instruments and circumstances that affected the observation process attracted a wider group of readers among scientists besides astronomers. In the texts, therefore, such talk can also be seen as functioning as a way of elevating the experimenter's status as a scientist, or as mirroring the scientist's thoughts or search for reinforcement from other scientists; namely, to write down the observations in a punctual manner was entangled with a deeper purpose that made visible the discourse of complimenting others or showing evidence of their mistakes and failures. Reid even called this kind of performative behaviour 'playing the astronomer', as the astronomer was in a precarious position on an expensive voyage as he was likely the first one among the crew to be seen as less important and as excess weight.²⁷

In this light, it is interesting to examine how instruments and bodies were referred to, as this reflects the general values that kept being repeated in the accounts. Simon Schaffer has suggested that the states of disrepair in observation reports or travel narratives refer simultaneously to the tools and to the humans that interact with them and with one another.²⁸ As he wrote, the states of disrepair helped distribute responsibility across cultures and spaces, offering resources to defend some reputations and damn others.²⁹ From this perspective, the referral to the external conditions and the others who contributed in the making of the observations were part of the pattern of this way of distributing the responsibility for scientific success and failure.

Referring to the sources and collaborators was also a matter of reliability. According to the semantic arrangement of the keywords in the topics 'Astronomer's weather', 'Environmental circumstances' and 'Travel narrative', the materiality of objects was closely linked with the circumstances of observing. Maskelyne's previously mentioned 1761 lengthy report was careful to mention and honour the builders and senders of the equipment,³⁰ and in a similar fashion while on a state-sponsored exploration voyage, another astronomer in his journal listed the people who had built or fixed the instruments he used.³¹ If no observation was possible due to fog or a broken instrument, their role in the experiment or its possible failure was at least taken into consideration in the description of the event. Hence, the keyword 'wood' is interesting. This might indicate the 'honouring' often offered the makers of the instruments used in the observations, as such compliments were written with full description of the types of materials used in building them and thus the

quantitative data also indicates the epistemological importance of the astronomical equipment.

Talking about the weather could also be an instrument of politics, as the making of science was, and is, very political. In the corpus, the weather was at times discussed in a text with what can be described as politeness or plain style. This structured a discourse which proposed openness towards the various possibilities and active influencing on the observer's circumstances. The impact of weather could not be controlled, but it could be understood by systematisation;³² and as it affected the success of observations and experiments, it was used as both an explanation and a weapon by scientists in the political game of making knowledge and acquiring more funding. Royal Society funding affected the discourse and the attempts to increase the natural history knowledge, and while only a nominal part of the Society's funding came from the king, the results and communications of scientific results needed to please the funders. John Henry has pointed out that this meant that the funders would wish to gain practical applications from the experiments and developments of science. As a result, the Society had to be very apologetic and have its value clearly propagandised in its attempts to demonstrate the usefulness of science to the state.³³ In order to maximise the attention within the administration, the importance and rarity of the observations of the singular 1761 and 1769 Transits of Venus would have given a reason to report the events with such care. It was a good opportunity to emphasise the relevance of the expensive astronomical observations, which was brought up wherever and whenever the transits were mentioned.

The final topic featuring the weather was 'Travel Narrative', consisting of plain or technical descriptions of weather, geography and exploration events. The topic was very frequent and steadily present by 6% to 9% throughout the period, but was at its largest at the turn of the 1770s. As weather has been proved to be an important part of spatial descriptions of 'new' regions, which were especially discussed around this time, it is most likely that there was a correlation between talks of weather and such new areas with promises for imperial and scientific explorations.

Having so many obviously different kinds of weather topics at the same time means that, simultaneously, many and varied aspects were considered. If some discussion has been very small (or unimportant) in its scale, it would not be visible in this kind of topic modelling of 1,421 articles.

Talking about instruments

Regarding the importance of various disciplines within astronomy, before 1758 and between the transits, there was according to the statistical results more room for showing interest in chemistry, whereas at the end of the 25-year period, the data indicates a turn towards widening discussions about the use of experiments and optical instruments. This was connected to experiments

of measurable phenomena such as air pressure, distance and microscopic life forms, and was influenced by technological developments (besides telescopes) that also led to increased use of three observation instruments in the form of the thermometer, the barometer and the hygrometer.

These were notable topics. The talk about the instruments and their particular use each received 6% to 10%, respectively, of the space of the published texts. However, the discussion was not fully diverted from astronomical topics, as the development of the instruments is linked to weather discourses. In fact, as the three new instruments became available to more observers, it was possible to collect much larger amounts of data of local and global weather patterns, so they could be systematised and understood not just as weather, but as climates. The influence of the political interests involved in producing the 'facts' of far-afeld weather should not be underestimated either. Morgan Vanek has suggested that the actual reason why 18th-century literature is saturated with the rhetoric of meteorological science lies in seeing the topic as a prominent and productive term in the public debate about Britain's imperial obligations. She claims that 18th-century writers amplified the threat of environmental influence to justify a British right to govern all over the world, as with their governance the British could improve living conditions in the 'new' harsh regions.³⁴

Finally, the last approach to astronomy is quite different from the others as it addresses a rather different mindset. Interestingly, together with the perspectives on the influences of various circumstances, at the time of the 1769 transit there was also the topic 'Ancient tradition' (with 6% of the text mass), which linked the new observational data with ancient calculations and beliefs. This might indicate the astronomers' certainty of the coming success in observing the second transit and their enthusiasm in comparing their innovations with other foundational theories. This could also discuss the many stages in which the rational thinking could be influenced when the collection of new knowledge in 17th- and 18th-century Europe was largely a cooperation among various specialised actors, where some collected field data and others depicted and analysed it. According to Francis Bacon, the different investigators (observers, experimenters and theoreticians) were in this required to be on guard against 'the idols', the profound and sometimes erroneous ideas created in one's mind, as well as the defective sensations of any particular individual.³⁵ Indeed, it sounds like a difficult business to create reliable knowledge navigating the circumstances of observation, various investigators and possible mindsets.

Conclusion: Nine Ways of Talking about Astronomy

In summarising the critical analysis of the topic modelling results, I suggest that during the third quarter of the 18th century *Philosophical Transactions* communicated astronomical topics in at least nine different ways. The actual events surrounding the two significant Transits of Venus and other aspects of astronomy naturally dominated the discussions in the years 1758–1762 and

1768–1772 and, connected to this, the periodical contained 24 topics that were common enough to be meaningful in the text-mining results. I located five ways of talking about astronomy that existed as temporal trends, emphasised only during the transit of 1761 or 1769.

The first two ways were especially common around the 1761 transit. These sub-themes explored *the meanings given to the systematisation of data*: they denoted the practical ways of describing raw data and the systematisation of results (and in fact ended up publishing the long lists of various observation results), or attempted *to reveal a system of the universe by theorising* the heavenly bodies. This reveals the emerging new natural philosophical ways of thinking about the universe.

The next three ways of talking in astronomical topics were particularly common around the 1769 transit. In the 1770s, both the instruments and circumstances of experimentation seem to have been included in a wide way of talking about observation, such as *how the surroundings and weather can influence the observing process*. The third way of talking then points to the lived experience of the field practices of astronomical observation. The fourth astronomical discourse addressed weather and geographical locations *as evidence for the technological advances and greatness of the empire that used them despite the environment and conditions*. The material conditions offered a strong rhetorical explanation to success and failure: honouring and complaining was linked to collaboration between the makers and users of the materials and also to accepted rules of polite communication. These two ways of talking also connect to Steven Shapin's research on the role of actorship in early scientific practice and my data suggests that it would be relevant to further explore the language and style of how one communicated one's research in early modern scientific networks. The fifth discourse linked events to their *tradition* and could be seen to guard the human senses against erroneous input.

The above five ways of talking were temporal trends that existed only during a part of the research period in question. There were also four continuous sub-themes that were observed in the data. According to the statistical appearance of topics, these four discourses were dynamic and their perspective might have changed over time, but nevertheless they continued in some notable form. These aspects were pointed out first and foremost via the digital method, although in retrospect it is easier to see and contextualise them as a part of the data.

The search for *reliable means of observation* was another theme that was characteristic in the entire period around the two Transits of Venus. The sixth astronomical way of talking concerned *the materiality of instruments, their use, and the practice of experiments*. The processes of observing and measuring would in this discourse be linked to trusting the results made through material objects, including the instruments, senses and the human body.

The seventh discourse also concerned the search for reliability and indicates that there continued to be some difference in the ways of making arguments

through *mathematical or physical causal reasoning*. While generally the quest between the causal and mathematical evidence for new knowledge is visible in many topics, the nuances or sub-themes appeared in temporal turns. For example, the topic 'Rules of the skies' lessened towards the end of the studied period, whereas experimentality seems to have become more common. In the two topics that concerned the measuring of distance, the discourse was split into two subsequent practices, with a different focus on the means of obtaining reliable measurements. In other words, this study revealed a temporal variability in what means of observation were seen as reliable.

The eighth perspective suggests that the Royal Society's interaction with its public in the form of its periodical typically proposed some flexibility and openness for developing knowledge, primarily through further experiments. The *openness to probabilities* indicates a structurally designed outlook on knowledge and aligns with the Society's values that everyone should themselves test the reliability of accepted truths through using thorough experiments. In 1758–1762, the astronomical topics tackled reliability issues with algebra and by systematising of results: the way to do this was through collecting large amounts of data and systematising them, which according to the results was a popular method regarding the first transit. At the end of the decade, in 1768–1773, the process of measuring and observing seems to have been more cautious in that it was giving more attention to probabilities, which indicates easier acceptance towards new open-ended scientific hypotheses and continuously *ongoing experimentation*. During the second transit, the tables and the raw observation data had still been published, but now with less importance than before, as the data lists are nowhere near as visible when compared to earlier observations. This means that the mechanical approach to systematise raw data into thematic lists was no longer a remarkable approach. Instead, the natural laws and mathematics were emerging as a more reliable explanation for proving the validity of the experiments.

And, finally, the ninth way reveals the publication of the scientific reports to have been entangled with *accepted social manners*. It illuminates the importance of the language in communicating about one's research.

Regarding the various individual topics, eight were discussed continuously across the whole period and only one of these (the 'Distance measuring process' topic) concerned astronomy. These topics displayed more general talk about the making of scientific knowledge through collecting and observing in the form of various 'plain' descriptions: the travel location ('Travel narrative'), the events and collected specimens ('Events, history, specimens'), events in a polite style ('Events supposing politeness'), 'new' species ('Species') and observation reports ('Reports'), the last two accounting for up to 5% of the temporal change, although usually being less. The descriptions of these 'standard' observations continued to be presented in mostly stable amounts throughout the period. Among the continuous topics, the relationally biggest temporal change from a large amount (6% or 8%) to virtually nothing took place with regard to

the most specific topics (relating to the states of substances and environmental circumstances). These findings about the ways of talking are also supported by the findings of Teich's linguistics team, who noticed, interestingly, that some of the major changes occur for non-thematic topics, as the method brought out 'the hows' of the discourses.³⁶ However, the non-thematic 'hows', by which I mean the values and themes inside the discussions, are the most interesting results. These 'hows' describe the ways of doing or speaking (for example, through polite language or by expressing caution towards various probabilities).

Many results in this study were 'exactly what one would expect'³⁷ according to the research literature. Hence, it was pleasing to begin the analysis with those results as they seemed to confirm that the topic modelling had been carried out correctly. While the results in this way often confirm an earlier hypothesis, the real value of topic modelling is, however, in generating new ways of examining our materials, to deform them.³⁸ I see this as an opportunity to remove all the expected details and to reveal what surprising new findings are left. It is in this way that this study has shown how a well-known but manually too large research material can present different historical insights when interrogated through computational distant readings of digitised sources, thus illuminating the underused methodological opportunities for historians. The power of topic modelling really emerges when we examine change of the thematic trends across the entire text collection. This means that the temporal changes become visible as the topics are listed at intervals in a longer period.³⁹ As the case of the talk of 'distance' demonstrated, the comparison of two topics of the same theme resulted in noticing both a general discourse and located particular themes and also different ways to talk about them.

The temporal change of the paradigm was not seen directly in the results sheet produced by running the data corpus through MALLET, but became visible when interpreting the results through their contextualisation as a part of the well-known events within the history of science. As a list of words, composed statistically by an algorithm which knows nothing about the context of the study, the keywords per se are not the conclusion to our research questions. Rather, the key is the joint participations of the results and the researchers' insights and contextualisation, which is the approach that produces the hidden underlying meanings of the texts in *Philosophical Transactions*. Examining my familiar sources with this new method has, in other words, been beneficial to help me better understand the big phenomenon of the new emerging practice of science, which is a result that is much more important than just creating a general understanding of how scientists were talking in different ways about Venus.

Appendix 14.1: The Topic Labels and Keywords

Environmental circumstances: observations side air light difference lower years rain observation circumstances acid diameter set table latitude height scale electric force highest

Heavenly bodies: water sun parallax comet eclipse event it's wheel earth green-wich crystals cos axis chance coins square moon's nerves orbit lungs

Astronomical distance: feet limb observations sun foot cos inches velocity star measure est distance meteor modes cum electrified mercury black diapason wheel

Ancient tradition: birds venus transit clear blood ancient quadrant spot satellite vesuvius highest morning density roman horizon dist rest instrument charcoal observatory

Transit and Latin: longitude light contact weight vero transit clouds inter hoc contained servant primarytopic enim tab south city happen sky vapours hujus

Solar system: side quae moon vel stone observation clear degree read fpage earth sed height sin solis corpusbuild letter lpage latitude quod

Rules of the stars: venus ditto clock center moon's system veneris vertical solar miles column atque wood maskelyne mons sun's horizontal egress meridian quidem

Astronomer's weather: ditto air limb wind fluid sun time cloudy amp part clock salt june lowest contact bird matter clouds fixed north

Distance measuring process: distance experiment made experiments glass case great appears give proper state means degrees small method observation general appearance line places

Ancient manuscripts: observations inscription greek appears word fig hours inscriptions pag urine birch cliff emperor lead spindle steam tumor cells things father

Telescope observations: sun's parallax apparent cape telescope pro paris error wire power west etiam rev minutes issn etruscan rest centers april seconds

Travel narrative: made equal water observed body called half surface good kind sur place weather fpage received inches force white ground plate

Events, history, specimens: water large likewise issn days manner strong thing william inches red applied increase place easily larger numbers discovered cut history

Events supposing politeness: time found great day letter part parts matter title amp;c bodies proportion difference present mentioned till vol suppose power fire

Species: number quantity small fig air philosophical heat sun feet appeared considerable fla iron species corpusbuild lpage sea true end long

Reports: part point amp;c greater manner parts sir put end primarytopic years london left observed june substance observe order lightning animal

Hygrometer measurements French: temperature qui une proportion inch conductor form lgs hygrometer mountains luc's cette nous anemones deux open general aug sides temperatures

Thermometer, electricity and effects: heat des thermometer degree electric-ity column surface series instrument effect inches heights birds electrical torpedo boiling hill columns top common

Barometer measurements French: air les quicksilver barometer height tube experiments dans hath pour metal sur point fish ball density expansion shock ces par

States of substances with jargon: motion colour common form earth read kind sir learned bottom stones mercury spirit james measure england head lib miles proved

Notes

- ¹ Moxham 2016: 469.
- ² Byrch 1761; Dunn 1761, *The L&P V*: 102–103.
- ³ See, e.g., the correspondence regarding the transport and arrival of the instruments by Maskelyne in 1760.
- ⁴ See Valle 2006; McDougall-Waters, Moxham & Fyfe 2015; Moxham & Fyfe 2018.
- ⁵ Kermes, Degaetano, Khamis, Knappen & Teich. 2016a.
- ⁶ I wish to express my gratitude to them for generously allowing me to use the data corpus that they had pre-processed in their project ‘Information Density and Scientific Literacy in English: Synchronic and Diachronic Perspectives of the Collaborative Research Centre SFB 1102’.
- ⁷ Kermes, Degaetano, Khamis, Knappen & Teich 2016b: 1929.
- ⁸ Shawn, Weingart & Milligan 2013.
- ⁹ Fankhauser, Knappen & Teich 2016: 498.
- ¹⁰ Their project has already been finished and I have not collaborated in the research, but I was later permitted to use their open data. On another view upon collaboration, Matthew Kirschenbaum described the cooperation as also being ‘a social undertaking. It harbors networks of people who have been working together, sharing research, arguing, competing, and collaborating for many years.’ See Kirschenbaum 2016.
- ¹¹ In addition to the 20 discussed topics (see Appendix 14.1), there were five topics (making 25 topics in total) that were unrelated to astronomical issues, and were therefore excluded from this study. The excluded six topics focused on medical knowledge, nutrition, mortality rates, paleontological finds and geographical events such as earthquakes.
- ¹² In this topic occurs the keywords *fpage*, *corpusbuild* and *lpage*, which derive from terms used for the metadata included in the JStor text files and not from the original articles. This error originates in the pre-processing of the data: had it been noticed earlier in the research process, the corruption of the topic could have been avoided by including these terms in the stop word list. The topic has, however, been accepted as a part of the analysis in its partly erroneous form, as it was not considered to skew it considerably based on the reason that the keywords did not appear in the earliest part of the topic but as the 10th, 16th and 18th in the order of appearance. In topic modelling with MALLET, the earliest keywords have more significance in the analyses of the topic’s meaning than the later ones in the list.

- ¹³ Maskelyne 1761.
- ¹⁴ My depiction was guided by a similar analysis as in Mohr & Bogdanov 2013: 554.
- ¹⁵ Henry 2017: 168.
- ¹⁶ See Çimen 2018.
- ¹⁷ Topic ‘Transit and Latin’ uses keywords like ‘servant’, which indicates polite letter writing and, in the case of the Royal Society, very probably a set of observations sent to them.
- ¹⁸ Fankhauser, Knappen & Teich 2016: 498.
- ¹⁹ Golinski 2017: 181.
- ²⁰ Jardine 1999: 141.
- ²¹ Halley 1716: 246; Leverington 2003: 143.
- ²² Gascoigne 2000.
- ²³ Maskelyne 1761: 562.
- ²⁴ Turner & Turner 1998: 30.
- ²⁵ Maskelyne 1761: 563.
- ²⁶ Galison & Daston 2008: 316.
- ²⁷ Reid 2008: 172.
- ²⁸ Schaffer 2011: 708.
- ²⁹ Ibid.: 709–710.
- ³⁰ Maskelyne 1761: 560.
- ³¹ Wales 1777: 73.
- ³² Hooke 1663; cf. Daston 2015.
- ³³ Henry 2017: 174.
- ³⁴ Vanek 2016: ii–iii.
- ³⁵ Sargent 2012, 83.
- ³⁶ Fankhauser, Knappen & Teich 2016: 498.
- ³⁷ Blevins 2010.
- ³⁸ Shawn, Milligan & Weingart 2013.
- ³⁹ Blevins 2010.

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