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EARLY QUANTIFICATION OF SCIENTIFIC KNOWLEDGE: NICOLAAS STRUYCK (1686-1769) AS A COLLECTOR OF EMPIRICAL DATA

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In the history of science the eighteenth century has attracted less attention than other periods. While the seventeenth century with its turbulent and often sensational confrontation with, and victory over, classical Aristotelean science has been studied extensively; while on the other hand the nineteenth century with its far-reaching mathematization and professionalization of science has had many a monograph devoted to it, the historiography of the intervening eighteenth century leaves much to be desired.[1]

Yet the eighteenth century is a fascinating period, during which the seeds were sown for many novel scientific developments. Whether we look at electricity, chemistry, wave optics, meteorology or mathematical physics, the eighteenth century is for all these areas either a starting point or a turning point, at which a novel phase was inaugurated. It is the period when the collecting mania inspired by Bacon led to the first attempts at systematization and classification, of which Linnaeus's *Systema Naturae* from 1735 is the most important example.[2] This penchant for collecting was not limited to natural history specimens and curiosities. Partly as a result of the development of more and better mathematical and physical instruments, which became more widely available only in the beginning of the eighteenth century, science was confronted with the informative value of numbers. Sequences of measurements appeared on the one hand to be the key to scientific knowledge, but on the other hand the mathematical apparatus to deal with these

1 A number of wishes, summarized by Rousseau *et al.*, *The ferment of knowledge* are still unfulfilled.

2 In accordance with Stafleu, *Linnaeus and the Linneans.*

data was still largely lacking. As a result the first meteorological networks that were organized in the eighteenth century all became bogged down in the large amount of information collected that could not be handled. Yet the eighteenth century is pre-emeninently the age of the emergence of numbers as bearers of information.[3]

Nicolaas Struyck as a mathematician

We want to illustrate this development by the wide-ranging work of the Amsterdam mathematician Nicolaas Struyck (1686-1769) - for Struyk can definitely be called wide-ranging. He made original contributions to the fields of geography, astronomy, entomology, algebra, probability calculus, chronology, cartography and several other areas. He is especially well-known for his work on actuarial mathematics and population statistics.[4] First and foremost Struyck was one of the Dutch pioneers in the area of quantification of scientific knowledge, a field that today would be considered part of statistics.[5] The historian of science Dirk Struik (no relation) has called Struyck 'the most important Dutch mathematician of his time'.[6]

Little is known, unfortunately, about Struyck's childhood and education. He was born on May 21, 1686, in Amsterdam as the second son of the goldsmith Nicolaas Struyck Nicolaaszoon and his wife Geertruy Wesdorp. The Struyck family were faithful members of the Lutheran church in Amsterdam. In 1668 Struyck senior had been asked to lay the foundation stone of the *Nieuwe Lutherse Kerk* (New Lutheran Church) at the Singel canal, and Nicolaas Struyck would remain a dedicated Lutheran all his life.[7]

3 In accordance with Frängsmyr *et al.* (eds), *The Quantifying Spirit.*

4 For Struyck's scientific work see, amongst others Van Schevichaven, *Bouwstoffen*, 107-116; Vollgraf (ed.), *Les oeuvres de Nicolas Struyck*; Van Haaften, *Nicolaas Struyck*; Sofonea,'Nicolaas Struyck e le sue ricerche sulla mortalitá'; Pearson, The history of statistics, 329-347; and finally my own dissertation *Van 'konstgenoten' en hemelse fenomenen.*

5 As is explained elsewhere in this volume, the notion of statistics evolved from its original meaning of '*Statenkunde*' (statecraft, description of states) to the methodic collection and analysis of phenomena relevant for science, administration and practical work.

6 'de belangrijkste Nederlandse wiskundige van zijn tijd.' Struik, *Geschiedenis van de Wiskunde*, 174.

7 Kooiman, *De Ronde Luthersche Kerk*, 49 and 202. At his death in 1769 Struyck bequeathed the sum of Hfl. 20,000 to the welfare fund of the Lutheran church in Amsterdam. For his estate see various acts in the protocol of the (*Lutheran*) notary Paulus van Hunthum in Amsterdam (GAA, NA 14147, June-August 1769).

The lack of information about Struyck's early days means that we can only guess about his education.[8] It is apparent from his later work that it must have been quite thorough. He was a competent linguist and had well-developed mathematical talents. It is therefore tempting (also in light of Struyck's wide interests) to make a link between young Nicolaas Struyck's education and the circle of amateur scientists that gathered in Amsterdam towards the end of the seventeenth century. Sophisticated mathematical, astronomical and geographical knowledge was certainly present there.[9]

From an early age Struyck was in contact with collectors of natural history specimens. On a modest scale he collected himself. As a little boy he went out with his father catching butterflies. Later in life he was to write that 'formerly insects were my favourite pastime'. In 1718 he had six substantial folio volumes with his own drawings of 'Various outlandish insects' and other natural history specimens.[10] Around this time his love of natural history must have turned into a passion for mathematics. But even in the field of mathematics he remained a collector: he gave his heart especially to applied mathematics. He no longer chased butterflies, but devoted his time to collecting empirical data, with the aim of discovering lawlike patterns in them.

This development was less strange than it may seem now. The collections of curiosities and natural history specimens in Dutch cabinets of the seventeenth and early eighteenth centuries were a small-scale reflection of the world as a whole. Not without reason the recent massive study of these cabinets bears the title: *De wereld onder handbereik* (The World within Arm's Reach).[11] The notion of geography prevailing at the time is the key to Struyck's wide-ranging interests. One of Struyck's great models, the geographer Varenius, defines this discipline as that part of mathematics that describes the condition of the earth and its parts, dependent on magnitudes and quantities, such as its shape, position, figure, motion and celestial phenomena.[12] Geography was seen as a branch of mathematics. This 'mixed mathematics', as it was

8 An uncle by marriage, Nicolaas Blancke (married to Anna Struyck Nicolaasdochter) was a Lutheran schoolteacher in Amsterdam. In Lutheran circles there was also Marten Calman (died 1726), 'a master of mathematics'. For his teaching see Van der Krogt , *Advertenties voor kaarten, atlassen, globes*, 464.

9 Cf. Vermij, 'De Nederlandse vriendenkring van E.W. von Tschirnhaus', 153-178. Cf. the same author, 'Genootschappen en de Verlichting', 3-23.

10 Cf. Smit et al., *Hendrik Engel's Alphabetical List*, nr. 1485. Struyck had sketched various insects from specimens in the cabinets of Albert Seba or Jacob ten Caate (cf. nrs. 795 and 1392).

11 Van Gelder et al., *De wereld onder handbereik*.

12 Porter , 'The terraqueous globe', 288. In 1750 Struyck was to contribute to the first Dutch translation and up-dating of Isaac Newton's adaptation of Bernhard Varenius main work *Volkomen samenstel der aardryks beschryvinge in het algemeen*, three

Nicolaas Struyck (1687-1769)

called, originated in the pre-Newtonian era, when the quest to discover the structure of the cosmos naturally centred on the Earth. Geography was therefore viewed as an important (if not *the* most important) part of mixed mathematics. On the basis of such a wide definition, the transition to population statistics or astronomy was easily made. From a contemporary perspective there is therefore an obvious unity in Struyck's diversity. In this respect Struyck is a fine example of how the present classification of scientific disciplines can easily lead to a distortion of the historical perspective. Struyck conceived of himself as a geographer. His first major work, full of mathematical, geographical and astronomical information, was entitled *Inleiding tot de Algemeene*

volumes (Haarlem, 1750). The third volume consists of 'supplements' with, amongst others, notes by Struyck and two fellow mathematicians from Haarlem, Dirk Klinkenberg and Jacob de Bucqoy.

Geographie (Introduction to General Geography).[13] In this volume, which was published late in 1739, Struyck presented the results of some twenty years of scholarship. We shall confine ourselves here to a discussion of those parts that testify to Struyck's early statistical activities. This aspect of his work can roughly be divided into two parts: statistics of comets and population statistics.

Struyck's motivation and his choice of subjects

Although Struyck does not express himself directly in his writings about his choice of subjects and his motivation, it would seem that a number of factors have been very influential. One of them was the breakthrough, around 1715, of Newtonianism in the Dutch Republic. Although Newton's famous *Philosophiae Naturalis Principia Mathematica* had been published in 1687, his ideas became influential on the European continent only after the publication of the second edition in 1713. The fact that a year later a pirated version of this edition was produced in Amsterdam also contributed to the wider distribution of this important scientific text.[14] Struyck had a copy of the Amsterdam pirate edition, and studied this text thoroughly.[15]

Newtonianism did not only introduce a new conception of physics, it also supplied people with an excuse to study the Creation. Seventeenth-century rationalism, especially Spinozism with its leanings towards atheism, had made

13 Struyck, *Inleiding tot de Algemeene Geographie*. This work, which was printed in the course of three years, consists of two divisions with their own pagination. In the first division Struyck discusses geography: the structure of the universe and the place of the earth in it. He also considers cartography, natural history, physical geography and population statistics to fall under the condition of the earth. The second division is largely devoted to more detailed astronomical and demographic topics. This last (demographic) part is to be found in French translation in Vollgraff (ed.), *Les oeuvres de Nicolas Struyck*, 164-249.

14 For the various editions of Newton's *Principia* see Cohen, *Introduction to Newton's 'Principia'*. For the two Amsterdam pirate editions see Van Eeghen, *De Amsterdamse boekhandel* vol. 5, 326-327.

15 In 1722 he thought he had found some printing errors in the Amsterdam edition. Struyck to De l'Isle, 4 april 1722 (OdP, *Corr. Delisle*, II, 41). That Struyck had access to the Amsterdam pirate edition of Newton's *Principia* of 1714 is apparent from *Inleiding*, II, 171. The combination of publishers reponsible for the Amsterdam pirate edition of Newton's edition in 1732 also published Struyck's adaptation of a French book on commercial arithmetic, to which Struyck added an essay of his own hand on determining exchange rates and other mathematical problems. Cf. Ricard, *Traité général du commerce*.

the study of nature suspect. Newton's view that a sacred 'Divine Plan' lay concealed in the Creation, which implied that the study of the products of Creation could reveal more about man's destiny, provided a novel legitimation of this kind of research.[16] In the Republic this theologically-inspired approach was advocated with great enthusiasm, erudition and success in a voluminous tome, entitled *Het Regt Gebruik der Wereltbeschouwingen* (The Right Use of World Views).[17] The book was very successful and a bestseller for many years (a sixth edition appeared in 1740). Its author was Bernhardt Nieuwentijt, medical doctor and mayor of the town of Purmerend and an expert on Newton's work.[18] Nieuwentijt's success undoubtedly influenced Struyck. Physico-theological ideas are certainly present in his work. However, contrary to many others, Struyck did not confine himself to devout contemplation, but focused on down-to-earth, empirical research.

Struyck was strongly influenced by the work of the English mathematician and astronomer Edmund Halley, one of the earliest Newtonians.[19] Halley was also a wide-ranging scientist. Today he is probably best known as an astronomer, but his scientific oeuvre also comprised work on pure mathematics, physics, archaeology, terrestrial magnetism, meteorology, navigation, population statistics and several other subjects.[20] Halley can therefore also be called a student of mixed mathematics. As a result there are remarkable parallels between Struyck's work and Halley's. Struyck might easily be called the 'Dutch Halley'.

Halley produced both the first scientific mortality table and the first table of cometary elements. Struyck followed in his wake and complemented or improved on Halley's work in both areas. Struyck was the first scientist who recognized the difference in mortality between and women in the mortality table that he published in his *Geographie* of 1740. In the same book Struyck made the first attempt to supplement Halley's cometary research. On the basis of further research Struyck managed, in 1749, to add eighteen cometary orbits to the original twenty four published by Halley. Struyck also discussed Halley's research into lunar eclipses. On the basis of a comparison of historical lunar eclipses Halley had concluded that the moon's orbital veloc-

16 Cf. van Lunteren, 'Newtons God en Newtons gravitatie'.

17 Cf. Bots, *Tussen Descartes en Darwin* and Vermij, *Secularisering en natuurwetenschap*.

18 Cf. Fellmann, 'The *Principia* and continental mathematicians', esp. 25-26.

19 In 1687 Halley acted as editor and financeer of the first edition of Newton's *Principia*.

20 Cf. Roman, lemma 'Halley' in *Dictionary of Scientific Biography*, VI, 67-72; also Thrower [ed.], *Standing on the shoulder of giants* and Hughes, 'Edmond Halley, Scientist'.

ity changes in the course of time. Struyck thought this conclusion was premature. A critical investigation of the original sources and an estimate of the (in)accuracy of the measurements made him conclude that everything was still open in this matter.

Halley's view that historical chronology had much to gain from the study of astronomical phenomena was another area where Struyck followed in Halley's footsteps. Struyck claimed that he had been able to date incidents related by English and French historians, because they mentioned astronomical events that he had found described in greater detail elsewhere. Struyck also took up Halley's famous suggestion about a possible way to determine the distance between the Earth and the Sun.[21] In doing so Struyck was one of the 'diligent searchers of the Heavens' to whom Halley had appealed to observe the two (rare) transits of Venus across the sun's disc in the sixties of the eighteenth century, when he himself would be long dead. From measurements performed at different places on Earth it would be possible to find the length of the astronomical unit, a fundamental distance that might be called the yardstick of the solar system, which at the time was known only very inaccurately.[22]

Although there were great similarities between the work of the two scientists, there was an enormous difference in their social status. Halley might be called a scientific professional: he was embedded in the English academic world, initially as clerk of the Royal Society of London and later as professor at a prestigious university; he always enjoyed royal protection, which finally resulted in his being appointed as Astronomer Royal, and the Royal Society was always there as an institutional scientific sounding board. Struyck's position was entirely different. For him science was not a livelihood.[23] He did not live *off* science, but *for* science, unhampered, but at the same time unsupported by any (royal) protection whatsoever. Struyck represents the pure 'amateur', full of curiosity, a man who, speaking about his own work, said: 'To examine this is not without use. One often investigates with the greatest difficulties things that do not lead to anything.'[24] In short, he is a splendid

21 Struyck, 'Berigt omtrent de verschijning van Venus in de zon'.

22 Cf. Van Helden, 'Measuring the solar parallax'.

23 It is not entirely certain how Struyck made a living during the first decades of his life. He probably either was a bookkeeper or had some function in the Amsterdam exchange business. He considered himself a mathematician, witness his denoting himself as '*mathesius*' when he registered as 'native burgher' of Amsterdam in 1724. Later in life (from ca. 1750) he capitalized on his scientific knowledge. From about 1750 he engaged in teaching apprentice bookkeepers and navigating officers.

24 'Dit na te gaan is niet onnut. Men onderzoekt dikwijls met groote moeite dingen die nergens toe dienen.' Struyck, *Inleiding*, II , 321.

VERVOLG
VAN DE
BESCHRYVING
DER
STAARTSTERREN,
EN NADER ONTDEKKINGEN OMTRENT DEN
STAAT VAN 'T MENSCHELYK GESLAGT,
BENEVENS EENIGE STERREKUNDIGE, AARDRYKSKUNDIGE
EN ANDERE AANMERKINGEN,
DOOR
NICOLAAS STRUYCK.
Lid van de Koninglyke Societeit van Londen.
Met Koperen Plaaten opgehelderd.

Te AMSTERDAM,
By *ISAAK TIRION*,
MDCCLIII.

Title Page of N. Struyck, 'Continuation of the Description of the Comets and Further Discoveries about the State of the Human Race, to which are added some Astronomical, Geographical and other Remarks' published in 1753 example of a successful dilettant, who was capable of producing work of a high scientific calibre.

The problem of cometary orbits[25]

It seems that Struyck started his mathematical work around 1712, when he was 26 years old. Like many beginning mathematicians at that time he first performed calculations of solar and lunar eclipses.[26] Soon after, however, he became fascinated by probability calculus. As is evident from his first publication, the *Uytreekening der kanssen in het speelen, door de Arithmetica en Algebra, beneevens een verhandeling van Looterijen en Interest* (1716) (Calculus of chances in gambling, by Arithmetic and Algebra, to which is added a Discourse on Lotteries and Interest), he was inspired by two innovative studies on the subject by Bernoulli and De Moivre, which had been published in 1713. In his own, anonymous publication, Struyck showed that he was well acquainted with the literature of the mathematical calculus of probability. He gave solutions to five famous problems that had been set by Christiaan Huygens in his *Van rekeningh in spelen van geluck* (On calculation in games of chance) (1657).[27]

Soon afterwards Struyck probably came across an article by Halley in the *Philosophical Transactions of the Royal Society* on the calculation of cometary orbits on the basis of historical sources. Halley's work was a extension of what Struyck had just read about comets in Newton's *Principia*. In Book III of the *Principia* Newton discussed the structure of the solar system, and about one third of his discussion was devoted to comets. Newton's principle of gravity could be applied to these heavenly bodies as well, and for many this came as a surprise. Before the publication of the *Principia* a fundamental difference had always been made between comets and planets. The motions of the planets had been known since times immemorial. Their regular passage along the ecliptic had been charted for such a long time, that in every world view they were considered constant phenomena with predictable motions. Planets were stability incarnate. How different were the comets! Their prime characteristic was their unpredictability.

25 This part is treated more extensively in my *Van 'konstgenoten' en hemelse fenomenen*.

26 Cf. Struyck, *Aanmerkingen*.

27 These problems also inspired mathematicians like Hudde, Spinoza, de Moivre and (Jac.) Bernoulli to discover solutions. Cf. *Pearson*, *The History of Statistics*, 330-332; See also: Van Haaften, *Struyck*, 45; and Korteweg, *Oeuvres Complètes de Christiaan Huygens*, 'Calcul des probabilités, travaux de mathématiques pures, 1655-1666', 29-31, 88-91, 108-110.

In his *Principia* Newton had demonstrated on the basis of the bright comet of 1680 that it followed with mathematical certainty from his principle of gravity that the orbit of a comet would be either an ellipse, a parabola or a hyperbola. There was no longer a fundamental difference between planets and comets. Only their initial positions and velocities in the solar system caused the conic sections along which they moved to have different excentricities. For comets the excentricity was so large that their orbits close to the sun could always be approximated by a parabola. As a result only five heliocentric coordinates were needed in these cases to determine their motions across the sky.[28]

After Newton Halley was the first to apply this theory to already available comet observations. For nearly a decade Halley searched in old sources for comet observations that allowed determination of five orbital coordinates. In 1705 he published the result in the *Philosophical Transactions*: a list of 24 cometary orbits, which became known as Halley's *Synopsis*. From a comparison of these orbital elements Halley concluded that it was extremely probable, as Newton had suspected, that comets move around the sun in very elongated ellipses. As his list contained three comets with very similar orbital elements, it was very plausible according to Halley that these comets, which had been seen at 76-year intervals, had been appearances of one and the same comet, which would return to the vicinity of the Sun around 1758.[29]

Halley's research had an enormous appeal to Struyck. He felt that Halley's *Synopsis* was 'a treasuretrove for the astronomers of future centuries.'[30] In a letter to the French astronomer and geographer De l'Isle in 1722 he said that he had been working for some time on a project to extend Halley's work on cometary orbits, 'imitating the great astronomer.'[31] It took nearly twenty years, however, before Struyck felt he could publish any results. In 1737 he finished a manuscript that he had printed by the Amsterdam publisher Isaac Tirion. In the same year he wrote a letter to Halley, in which he proudly announced

28 These are: the time of perihelion passage T (year, month, day, hour, expressed relative to a particular place on earth); the perihelion distance q (the shortest distance to the sun); the inclination i (the angle between the orbital plane and the plane of the ecliptic); the longitude of the ascending node, measured from the vernal equinox ; the argument w (the angle between the perihelion and the ascending node). Cf. Brandt & Chapman, *Introduction to Comets*, 63-64.

29 Halley was less sure about the two other comets, which should have to return around 1790 and 2255.

30 Struyck, *Inleiding*, II, 6.

31 'en imitant ce grand astronome.' Struyck to De I'Isle, April 4, 1722 (*Observatoire de Paris*, *Corr. Delisle*, II, 34).

the discovery of *eight* new periodic comets.[32] Curiously he omitted the empirical evidence on which his findings were based, so that Struyck's letter was presented at a *Royal Society* meeting as a short communication that did not attract any further attention. It seems he never received a reply from Halley.

When in 1740 Struyck's *Introduction* finally appeared in print, a large part of the book was devoted to the problem of determining cometary orbits. The most important part was undoubtedly his *Korte Beschryving van alle de Comeeten of staartsterren, die ik in de geschiedenissen heb kunnen vinden* (Short Description of all Comets or Caudate Stars that I have been able to find in Historical Accounts). This 'cometography' is generally considered to be the first critical study of the historical sources about comets ever published.[33]

Struyck was unusually critical for his time. He pleaded for a return to the historic source material whenever possible. The number of publications to which Struyck refers in his cometography is enormous. Originally Struyck wanted to include only those comets concerning the observations of which he was totally certain. Gradually, however, he adjusted his criterion by also taking the trustworthiness of the authors in question into consideration. If authors gave correct and verifiable information elsewhere in their historiography, he assumed that what they said about comets would be correct as well. Struyck recognized, however, that as a result his own 'history' might not be entirely free of errors, but, he said, 'one arrives at knowledge only by stages.'[34]

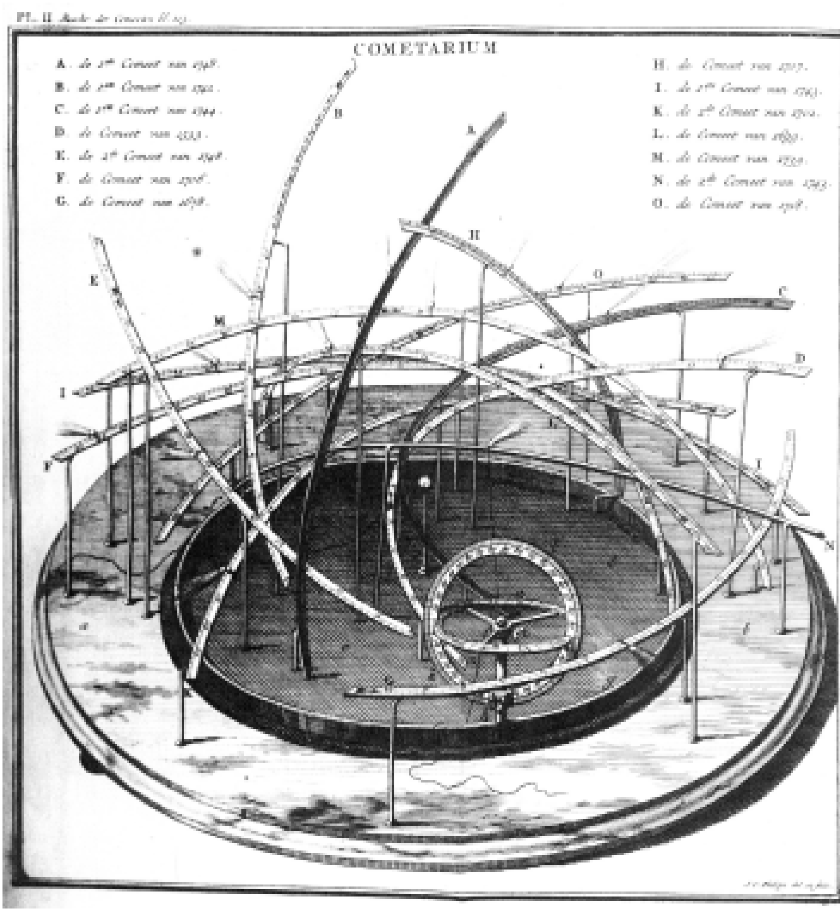
Struyck's ultimate aim was to supplement Halley's table of twenty four cometary orbits. His ambition was to discover similar orbital elements, so that a new periodic comet might be detected. By 1740 he had not yet been successful. His claim to have found eight new periodic comets was not based on similarity of orbital elements, but on a periodicity in the appearance of the comets.

Struyck often had no alternative but to concentrate on such a supposed periodicity. Most of the historical sources that mentioned comets did not give measurements from which Newtonian orbital elements could be derived. In the light of what we know today, Struyck's approach, later called the guesswork method by Pingré, was doomed to failure. At the time Struyck felt otherwise. This had everything to do with his own estimate of the number of comets in the universe. Struyck thought this number would not be larger than a thousand, of which in his opinion about a hundred belonged to the solar system. Only a third of those would be visible to the naked eye, 'yet

32 Struyck to Halley, September 17, 1737 (British Library, *Add. Mss.* 4434, vol. IV, fol. 145-146b/24, fol. 189-193).

33 Brown, *Halley's comet & the Principia*, 140; cf. Pingré, *Cométographie*, I, v-vi.

34 'men komt maar in trappen tot de weetenschap.' Struyck , *Inleiding*, II, 166.



Struyck's Cometarium, Picture published in Struyck's 'Continuation' (1753)

here there is still sand to count.'[35] This assumption, in combination with the fact that every comet had its own orientiation in space, made him suppose that it should be possible to discover identical comets on the basis of a critical study of the historical sources. If the number of comets had been small, he might indeed have been successful.

Struyck continued his research into comets to the end of his life. After the publication of his *Inleiding* (Introduction) in 1740 he carried on tirelessly. He

35 Struyck , *Inleiding*, II, 24.

conducted a correspondence with many scientists and institutions at home and abroad, in which he tried to obtain as many comet observations, both old and new, as possible. It took an enormous amount of time to distill the five heliocentric coordinates from the terrestrial observations. One set of parameters often required more than a week of calculations. The technique of calculation was, in part due to Newton's geometrical approach, extremely complicated. In principle the situation improved when Euler published an algebraic approximative method in 1744.[36]

In this matter, however, Struyck showed himself to be a transitional figure. He had grown up with Euclidian geometry, and he found it difficult to abandon the customary geometric approach; on the other hand he did not hesitate to use Euler's new methods when it suited him. This mixed approach will not have helped to shorten the length of his calculations. That at least is the opinion of Olbers, who remarked in 1797 that Struyck had saddled himself with a great deal of superfluous and time-consuming calculation.[37] Yet Struyck was able in 1749 to publish the first important supplement to Halley's *Synopsis*. While Halley had presented orbital elements of twenty four comets, Struyck now published his *Viae Cometarum*, a list of the orbital elements of nineteen comets, eighteen of which were new.[38] Five of these he had calculated himself. The elements of five other comets had been calculated by two of Struyck's friends.[39] The rest was a compilation of the work of foreign astronomers.[40] A new periodic comet, which he had ardently hoped for, was not among them. The empirical evidence for the orbital elements presented was published by Struyck in 1753 in his *Vervolg van de Beschryving der Staartsterren* (Continuation of the Description of the Comets).[41] In this book, which was meant as the second part of his *Inleiding op de Algemeene Geographie* (Introduction to General Geography), Struyck also gave a further analysis of the numbers he had found. The total number of comets from Halley's *Synopsis* and his own *Viae Cometarum* now amounted to 42. This opened the possibility of classifying the comets. He arranged the comets in 15 classes of increasing perihelion

36 Euler, *Theoria motuum planetarum et cometarum*. Struyck knew about this book from 1745.

37 Olbers, *Abhandlung über die leichteste und bequemste Methode*, 56-57.

38 Struyck, '*Viae cometarum*', 89-92. Also in *Nova Acta Eruditorum*.

39 The mathematicians Cornelis Douwes from Amsterdam and Dirk Klinkenberg from Haarlem.

40 Namely the Frenchmen De la Caille (3) and Maraldi (1); the Englishmen Bradley (2) and Bets (1) and the Swiss Loys de Cheseaux (1).

41 Struyck, *Vervolg van de Beschryving der Staartsterren.* This book also comprises two divisions with their own pagination. In the first division Struyck discusses astronomical topics, especially comets; the second division is largely devoted to population statistics.

distance and also provided a classification according to increasing inclination, in 9 classes of 10 degrees each.[42] These classifications were apparently meant to find some pattern that might lead to further insight. Although Struyck did not draw any conclusions himself, by doing so he did create the first cometary statistics. Present-day handbooks give Struyck's classification in a modern, but basically unchanged, form.[43] The cometary research of, for example, Hoek in the nineteenth century, and of Van Woerkom in the twentieth century[44] would have been inconceivable without sound cometary statistics, of which Struyck can be called the founding father.

Population statistics

With at least as much dedication Struyck worked on another project, to which he had also been inspired by Halley. The latter had published the first empirical mortality table in 1693 in the *Philosophical Transactions*.[45]

In his *Uytreekening der kanssen in het speelen* (Calculation of Chances in Gambling) of 1716 Struyck had already displayed his interest in probability calculus. In 1735 he turned again to the same field, this time in the form of mortality probabilities. In the last part of his *Inleiding* (Introduction) Struyck published three articles, viz., 'Gissingen over den Staat van het Menschelijk geslagt' (Estimates of the State of the Human Race), 'Uitreekening van de lijfrenten' (Calculation of Annuities) and an 'Aanhangsel' (Appendix) to the preceding chapters, which had been added at the last minute. These are Struyck's first important articles in the field of population statistics and actuarial mathematics. In the first paper he intentionally used the term 'estimates'. He felt that the figures on which he based his hypotheses were as yet much too uncertain. Struyck aimed at nothing more nor less than making a reasoned estimate of the total number of people on earth. He was intrigued by the question of whether the world population increases, is stable or decreases. In the first case the earth would become so full that not everybody could be supported, while in the last case the earth would become depopulated, 'both of which seem opposed to the purpose of the Creator'.[46] The question re-

42 Struyck, *Vervolg van de Beschryving der Staartsterren*, I, 15-16.

43 See, for example, *Brandt & Chapman*, *Introduction to Comets*, 66-69.

44 The Utrecht professor of astronomy, Martinus Hoek (1834-1873), claimed in 1865 to have demonstrated on statistical grounds the existence of so-called 'comet systems', which were later sometimes called 'Hoek groups'. Cf. Yeomans, *Comets*, 313-323.

45 *PT*, 17 (1693), 596-610; 654-656.

46 't welk beide tegen het oogmerk van de Schepper schijnen te strijden.' 'dat men nog een menigte van netter waarnemingen zal moeten hebben om met zeker-

mained: how to discover what was happening? It might be possible to determine the size of the population in a certain area from the annual number of deaths and births. But in order to make meaningful statements about the ratios in question, reliable counts were needed and these were not available. Although there were figures from various places in Europe, Struyck doubted they were reliable. He stated emphatically 'that a large number of precise observations will have to be made in order to find the number of the people in a place or country without counting them'. In the meantime Struyck investigated what the available figures revealed about the ratios of male and female births, of live births and stillbirths, about the contributions of various diseases to mortality, the numbers of marriages entered into and marriages dissolved by death, etc. These investigations led to a discussion of annuities. In 1617 Jan de Witt, the later Grand Pensionary, had published the first essay on this subject, and Struyck attempted to check De Wit's results with the help of a different approach, using logarithms. He warned, however, against a too great confidence in the formulas he had derived. According to Struyck, annuity calculations should not be based on mathematical equations, but on sound, empirically obtained mortality tables: 'Death does not obey our assumptions; these have to be derived from experience, otherwise one will always be on the wrong track.'[47] In short, Struyck wanted to test the assumptions empirically. In the 'appendix' that followed Struyck presented such a test. He had got hold of information concerning annuities that had been issued in Amsterdam in 1672 and 1673. In these contracts 1698 people had been involved: 891 women and 807 men. In the year of his investigation, 1738, 55 women and 45 men of the participants were still alive. There were precise records of when the others had died, and from this information Struyck could derive separate mortality tables for men and women. The difference between the sexes was significant, and Struyck immediately recognized the importance of this approach. He stated that, as far as he knew, no one before him had ever established such a difference. Struyck was right; the notion that men and women have different mortalities is deservedly credited to his name. Although the mathematician Kersseboom from The Hague later accused him of plagiarism on this point, the studies by Van Schevichaven and Van Haaften have shown convincingly that Kersseboom was wrong, and that Struyck was blameless.[48]

heid 't getal van 't volk in een plaats of land, zonder tellingen te vinden.' Struyck, *Inleiding*, II, 328.

47 'Het sterven luistert niet na onze onderstellingen; uit de ondervinding moet men die opmaken, of men is het spoor altijd bijster.' Struyck, *Inleiding*, II, 354. Also cited by Van Schevichaven, *Bouwstoffen*, 112.

48 Kersseboom, *Eenige aanmerkingen*. See for this controversy Van Schevichaven, *Bouwstoffen*, 124-125 and Van Haaften, *Struyck*, 16-17, 35-42.

In this 'appendix' Struyck also presented a test of his demographic 'estimates' on the basis of empirically collected material. One of his mathematical friends procured for him precisely kept records of the population of the village of Broek in Waterland for the period 1654 to 1738. The figures kindled such an enthusiasm in Struyck that in 1739, just before the publication of his book, he asked eight friends to count, not only the population of Broek in Waterland, but also that of five other villages north of Amsterdam.[49] The counting involved five thousand people. Struyck deemed the figures for the other villages necessary because he suspected that the composition of the population of Broek differed from that of most villages in North Holland. The results showed him, amongst other things, that more children were born in the villages than in the cities, a fact that Struyck did not ascribe to greater fertility in the villages, but simply to the circumstance that the cities attracted large numbers of single people from the *countryside*.

These activities gave Struyck a real taste for the empirical study of populations. After the publication of the *Introduction* in 1740 he continued the earlier investigations on a larger scale. According to Struyck, much remained to be discovered, as long as one built on experience. In 1753 in his *Nadere ontdekkingen noopens den staat van het menschelyk geslagt, uit ondervindingen opgemaakt* (Further discoveries concerning the state of the human race derived from experience), he argued that the true 'amateur' should not hesitate to adjust his earlier opinions. He himself had in the meantime collected information that undermined some of his earlier claims. He gave this information nonetheless, 'so that other amateurs may make further investigations.'. For, whatever one may do to suppress the truth, 'it will emerge again in the succession of time with greater lustre.'[50]

While in 1739 Struyck had organized a population census in five villages (something he thought he was the first ever to have done deliberately), in the period 1741 to 1743 he arranged this investigation on a larger scale. Through the mathematician Jacob Oostwoud, who kept a boarding school in East Zaandam, he mobilized seventy assistants, who went from door to door through much of Holland north of Amsterdam in order to collect population information.[51] Struyck himself took care of a part of Amsterdam. With this net-

49 Struyck, *Inleiding*, II, 385-389. Here the names of the villages are given as well as the names and occupations of the counters. The occupations are master painter, precentor, burgomaster, experienced mathematician, or a combination of these occupations.

50 'opdat andere liefhebbers dit nader zouden onderzoeken'. 'zij komt in 't vervolg van tijd met meer luister wederom te voorschijn.' Struyck, *Vervolg*, II, 1.

51 Of 33 of his assistants Struyck does not give an occupation. Of the rest most (21) were working as schoolteachers, six worked for the city government; three

74 NADER ONTDEKKINGEN NOOPENS DEN STAAT

* *Getal van Huizen, Huisgezinnen en Menschen, onder het Klokslag van Loenen. Ao. 1741.*

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Loenen Stigts in het Dorp	65	83	60	60	9	24	37	36	48	44	17	30	9	1	375
Loenen Stigts buiten het Dorp	48	45	32	32	1	8	23	11	27	25	12	7	1	0	179
Aan de Schans te Nieuwersluis	17	27	22	22	0	6	6	5	17	16	7	8	0	0	109
Loenerfloot	12	16	8	8	2	4	10	7	6	5	6	7	3	0	66
In het Stigtse te samen	142	171	122	122	12	42	76	59	98	90	42	52	13	1	729
Loenen Hollands in het Dorp	33	45	30	30	3	18	7	15	37	28	12	8	12	2	206
Loenen Hollands buiten 't Dorp	21	24	16	17	4	1	12	12	17	13	16	17	5	0	126
Mynden	25	23	22	22	2	3	2	9	23	21	15	7	0	1	127
Oud-over	42	76	59	59	3	13	19	22	51	49	12	20	17	0	324
In het Hollandsche te samen	121	168	129	130	12	35	40	57	128	111	55	52	31	3	783
In het Stigtse	142	171	122	122	12	42	76	59	98	90	42	52	13	1	729
In het Hollandsche	121	168	129	130	12	35	40	57	128	111	55	52	31	3	783
In 't Hollandsch en 't Stigtse	263	339	251	252	24	77	116	116	226	201	97	104	44	4	1512

Statistical Table from 'Further Discoveries' (1753) showing the 'Number of Houses, Families and People, 'under the Bell Sound' (in the Neighbourhood) of Loenen'

work of assistants he collected a wealth of information, part of which found its way, via Struyck's publisher Tirion, to one of the first Dutch statistical projects in the classical sense of the word: the *Tegenwoordige Staat der Vereenigde Nederlanden* (Present State of the Netherlands).[52] From this empirically obtained material concerning more than forty thousand people Struyck derived a number of general conclusions. He was especially interested in various ratios. He determined the ratio between men and women, between the number of married couples and annual births; he determined mortality figures; marriage figures; ratios concerning widows and widowers; between families and single people; even the occupation rate per house did not escape his attention. He contrasted these results with figures he had found in recent literature. For example, he dealt at great length with the book *Die Göttliche Ordnung* (The Divine Order), published in 1741, by J.P. Süßmilch, with whom Struyck exchanged letters in 1742.

were doctors or chirurgeons; the others were pastor, merchant, watchmaker of tax collector.

52 This English-inspired project was undertaken and executed by Tirion during the forties of the eighteenth century.

Influence

The enormous increase in Struyck's international correspondence characterizes an important difference between his *Inleiding* (Introduction) of 1740 and his *Vervolg* (Continuation) from 1753. Both in his astronomical and his demographic work Struyck attempted to get in touch with others. He attached greater importance now to his correspondence as a source of information. While not a single letter is mentioned in the *Inleiding*, in the *Vervolg* scores of letters from all parts of Europe are referred to, and in his later articles it is also apparent that Struyck had a large network of correspondents.[53] Amongst those involved were some of the most renowned scholars in Europe. On his list of correspondents figure the names of Halley, Euler, Bouguer, De l'Isle and De la Caille. This development is of course a reflection of the growing appreciation for Struyck as a man of science. After the publication of his *Viae Cometarum* in 1749 he was elected a Fellow of the Royal Society of London, on which occasion Martin Folkes, the President of the Society, spoke of his work in the highest terms.[54] In 1755, after Struyck had provided logistic support for De la Caille's astronomical expedition to the Cape of Good Hope, he was appointed an official correspondent of the *Académie Royale des Sciences* in Paris. In the same year the recently founded *Hollandsche Maatschappij der Wetenschappen* (Holland Society of Sciences) in Haarlem invited him to become a member. A number of scientists visited Struyck in Amsterdam. We know of visits by the astronomers De la Condamine, Chappe d'Autroche, Pingré, Messier and Ferrner.[55]

And yet the general impression in the literature is that Struyck's influence was limited.[56] There is no doubt that he was well known in the Netherlands. With some exaggeration he has been called *'the father of Dutch life insurance'*.[57] His contribution to actuarial science was at least so important that Schevichaven starts the second period of actuarial science in the Netherlands with Struyck.[58] In other countries, however, Struyck's work is mentioned only sporadically. Only in 1745 his *Inleiding* (Introduction) was first studied by somebody outside the Netherlands (De l'Isle), even though Struyck made sure that his work was distributed far and wide. But already in 1749 De la Condamine remarked that Struyck's 'merits could not have failed of being known

53 See App. I for Struyck's overview of his correspondents.

54 See App. II.

55 Cf. my *Van 'konstgenoten' en hemelse fenomenen.*

56 Cf. Pearson, *The history of statistics*, 347.

57 *'vader van de Nederlandse levensverzekeringen,'* Kooiman, *De Ronde Luthersche Kerk*, 49.

58 Van Schevichaven, *Bouwstoffen*, 107.

to all men of learning if his works had been published in a Language more generally understood.'[59] This complaint about the inaccessibility of the Dutch language was to be repeated many times during the eighteenth century: by Du Séjour, Pingré, Lalande, Montucla and Olbers. At best he was referred to, but he was not really read. A contemporary French survey of scientific progress mentioned as Struyck's only achievement that he had been the first ever to calculate the average duration of marriages.[60]

In historical perpective Struyck now receives greater appreciation. Pearson considers him 'a more important forerunner in the field of vital statistics than Süssmilch'; 'a man, who, although he lacked the mathematical genius of the Bernoullis, was entirely at home in the contemporary literature and who did not hesitate to formulate relevant questions'. Pearson, too, concludes that 'the knowledge of his memoirs and his reputation would be incomparably greater, had he been born in England, France or Germany.'[61] This is certainly the case if we also take Struyck's intensive work in astronomy into consideration. If he had been equally fortunate as his great model Halley, we might now have seen Struyck's comet returning to the vicinity of the sun. It did not happen. Yet Struyck's passion for empirically obtained numbers, and especially his modern critical and analytic powers compel great respect.

The first fragile signs of an 'institutional' embedding of research

We have to realize that Struyck could not fall back on an institutional framework. Until 1752 there was no scientific organization in the Republic of the Seven United Netherlands that was recognized or supported by the government. The universities were mainly focused on teaching and the professors were only sporadically interested in scientific research. Scientists outside the universities like Struyck had to find their own way. Stimulated by the emerging Newtonianism, in several towns in the Republic informal societies of 'amateur-dilettants' were formed or became active again, the members of which addressed each other as 'fellows of the arts' (*konstgenoten*). In cities like Haarlem and Middelburg such societies even acquired a building and instruments for demonstrations and research. Struyck's works were of course read in these circles. The surveyor Klinkenberg, for example, was a member of

59 Stated in Struyck's assignment as Fellow of the Royal Society of London (RSL, *Register Books*, 412, November 23, 1749). The election came into effect on February 22, 1750.

60 Savérien, *Histoire des progrès de l'esprit humain*, 55.

61 Pearson, *The history of statistics*, 347.

the Haarlem *Natuur- en Sterrekundig Collegie* (Physical and Astronomical Society). He acquainted himself with the calculation of cometary orbits with the help of Struyck's *Inleiding* (Introduction). This stimulated him to make precise and intensive observations, which in 1743 resulted in the first discovery of a new comet. Many more such discoveries were to follow. An intensive correspondence between Struyck and Klinkenberg was the result. In 1750 both contributed to the Dutch translation of Varenius' *Geografie*.[62] Another *konstgenoot* from Haarlem, the shoemaker Nicolaas Duyn, followed Struyck in his investigations into population statistics. Although Duyn was not in the same league with Struyck as a mathematician, the inspiration led again to original research.[63] In Amsterdam an attempt was made to found a similar 'art society', but as far as can be established this initiative was not successful. Struyck did become involved, however, with the scientific journal that was started in 1757 by his friend Martinus Houttuyn and a few others. Struyck contributed no fewer than eighteen articles to the journal, which appeared till 1765 in ten volumes. With Houttuyn, who visited him every week, he also made astronomical observations. Obviously, Struyck was part of a network of contacts. That Struyck was aware of the importance of this network for his scientific work is apparent from the fact that when he died in 1769 he remembered a number of his early scientific friends with a legacy.[64]

One of them, Jacob Oostwoud, continued from 1755 an initiative taken the year before by another mathematical friend of Struyck, Pieter Karman, to keep the interest awake of the circle of teachers and other devotees of mathematics, that had played such a crucial role in Struyck's population studies. A mathematical magazine was founded aimed at this group that appeared under the title of *Maandelijkse Mathematische Liefhebberij* (Mathematical Monthly Pastime), which in addition to all kinds of arithmetical problems contained various news items from the mathematical world.[65] From the group of readers of this teachers' magazine the *Wiskundig Genootschap* (Mathemat-

62 Editor Jan Bosch was also member of *Haarlems Natuur- en Sterrenkundig Collegie*.

63 Duyn [= Duin], *Aanmerkingen en aanteekeningen*. The remainder was issued after Duyn's death with a new title page: Haarlem (J. Marshoorn & I. Van der Vinne, 1746. For Duyn see also Van Schevichaven, *Bouwstoffen*, 167-171 and Sliggers, 'Honderd jaar natuurkundige amateurs in Haarlem'.

64 Among others Houttuyn and Oostwoud. Cf. see my '*Van 'konstgenoten' en hemelse fenomenen*'.

65 Oostwoud, *Maandelijkse mathematische liefhebberij*. The only copy that I know of is in the Library of the University of Amsterdam: sign. XX 834. Cf. also Honig, 'Jacob Oostwoud'.

ical Society) was formed in 1778, which still exists. Its motto 'tireless labour overcomes everything' would definitive have appealed to Struyck.[66]

66 'een onvermoeide arbeid komt alles te boven.' Cf. Van Haaften, *Het Wiskundig Genootschap* and Baayen, 'Wiskundig Genootschap, 1778-1978.

Appendix I: Register of Nicolaas Struyck's correspondents

(* = correspondances (partly) retained – *[b]* = concerned Population Statistics)

1.	Pierre Bouguer (1698-1758)	Paris	1755-1757
2.	César-François Cassini de Thury (1714-1784)	Paris	1753
*3.	Nicolas Louis de la Caille (1713-1762)	Paris	1746-1761
4.	Count Cerati	Rome	1745? *[b]*
5.	Jean-Philippe Loys de Cheseaux (1718-1751)	Lausanne	1746
*6.	Charles Marie de la Condamine (1701-1774)	Paris	1745-1753
*7.	Marie J.A.N. Caritat, Marquis de Condorcet (1743-1794)	Paris	1769
8.	Dr. Cunningham & John Foster	Dublin	1748
9.	Leonard Euler (1707-1783)	Berlin	1749
*10.	Edmund Halley (1656-1742)	London	1737
11.	J. van der Hey	Amsterdam	1761 *[b]*
*12.	Joseph-Nicolas de l'Isle (1688-1768)	Paris & St.Petersburg	1722-1723; 1745-1760
13.	Willem Jacob 's-Gravesande (1688-1742)	Leyden	1722
14.	Frans Hemsterhuis (1721-1790)	The Hague	
15.	Eberhardt Christiaan Kindermann	Dresden	1748-1749
*16.	Dirk Klinkenberg (1709-1799)	Haarlem & The Hague	1742-1764
17.	Samuel Koenig (1712-1757)	Franeker	1746
18.	Charles Mason (1770)	Cambridge	1747-1752
*19.	Gerard Meerman (1722-1771)	The Hague	1742
20.	Charles-Joseph Messier (1730-1817)	Paris	1763-1764
21.	Jan de Munck (1687-1768)	Middelburg	1739-1745
22.	Simon Panser (1699-1754)	Embden	1740 *[b]*
*23.	Alexandre-Guy Pingré (1711-1796)	Paris	1760-1763
24.	Du Pré de St. Maur	Paris	1752 *[b]*
25.	Cromwell Mortimer (1752)	London	1743-1744
26.	Jacob Oostwoud (1714-1784)	East-Zaandam	1737 (e.v.)
27.	Graaf Louis Riario	Rome	1741? *[b]*
28.	Adriaan Spinder (1758)	Haarlem	1737
29.	Gerrit Spinder (1758)	Krommenie	1737
30.	Johann Peter Suszmilch (1707-1767)	Berlin	1743 *[b]*
31.	Giuseppe Pancrazi Tetino	Livorno	ca. 1740 *[b]*
32.	Johann Friedrich Weidler (1691-1755)	Wittenberg	1750
33.	Eustachio Zanotti (1709-1782)	Bologna	1742
*34.	*Académie Royale des Sciences*	Paris	1752-1762
*35.	*Hollandsche Maatschappij der Wetenschappen*	Haarlem	1755-1767
*36.	*Royal Society of London*	London	1750-1756

Appendix II:

Contemporary discussion of N.Struyck, *Inleiding tot de Algemeene Geographie Benevens eenige Sterrenkundige en andere Verhandelingen*, Amsterdam (I.Tirion), 1740 by Martin Folkes, president of the Royal Society of London in the meeting of February 15, 1750. *[2 pp. Eng.; RSL Letters & Papers II, 43.]*

An account of Mr. Struycks book by the president.
Read Feb. 15, 1750[67]

'Mr Struyck of Amsterdam, now a candidate for the honor of being elected into the Royal Society, presented a few month since, a book formerly published by him, in the Flemish or Low Dutch Language: which being but little understood in this country, it is apprehended that the book may hardly have been taken notice of, so much as its contents. and the knowledge of the author, and the pains he has taken, seem really to deserve. This work, which was printed in 4^{o} at Amsterdam in the year 1740 is entitled *An Introduction to Geography, or the knowledge of the terrestrial globe with the elements of Astronomy, and an account of the several phaenomena that are most remarkable in the heavens.* Wherein the author, out of laudable desire to instruct such of his countryman as are neither versed in the learned or the foreign languages, has been willing to collect together for their use, from almost all the authors that are extant upon the subjects he treats about, a general account of what had not before been published in his mother tongue. He has accordingly begun by a general view of the Solar System, he has treated of the Sun, Planets, and their Satellites, with their several magnitudes and distances, as now discovered by the most accurate observations of the moderns, compared with those more imperfect ones handed down to us from the ancient Greek an Roman writers, as well from the Arabians, among whom the knowledge of Astronomy was preserved, when it was at its lowest ebb in the western world. Here he has introduced all the discoveries made with telescopes, and treated concerning the real orbits, described by the Planets in immovable space; and in considering of the globe of the earth, he has occasionally spoke of its mountains and their heights, of its mines, and different minerals, and besides explained the theory of the rainbow, and other remarkable meteors, with a short view of the natural history of its vegetable and animal productions. He has also delivered the theory of navigation, with the nature of the rhumb lines, and the use of Mercators chart, together with an account of the several ways in which the longitude of places has been endeavoured to be ascertained.

The author afterwards enters more particularly into the doctrine of Eclipses; he has considered the path of Solar Eclipses over the terraqueous globe, and has collected together a Table of all the Eclipses both of the sun and moon, which he could meet with any account of in books, from the year before Christ 721 to the year of our Lord 1469: the beginnings, middles, endings, and quantities of all which he has computed from the best tables. To these he has also added from Manfredi, an account of all the eclipses from 1740, when he published his book, to the year 1764,

67 In the document 1749, but this is ancient style.

and lastly 20 eclipses between the year before Christ 143 and the year of our Lord 70, which he has collected from the accounts of the Chinese history of chronology. The Author besides treats particularly of whatever has been observed most remarkable, in or about the bodies of the Planets, with the theory and eclipses of the Satellites both of Saturn and Jupiter; after which he gives the Newtonian and Halleian doctrine of Comets, teaches the ways of computing and constructing of their orbits, and lastly gives from Riccolus, Hevelius, and others, an account of all those whose appearances are any where taken notice of in authors, from the earlyest times to the year 1739.

Mr. Struyck has also given an account of what has been observed most singular among the fixed stars, such as new stars, stars that have disappeared or changed their magnitudes, the phaenomena of the milky way, and the like, and he has occasionally brought into his work many curious remarks, relating to the constitution of the globe we live upon, and its inhabitants, such as the principle of political arithmetic, the numbers and encrease of mankind, the proportion of males to females, the period of human life, and the comparison between several of the most populous cities, with very many other particulars both of use and curiosity, and all which he delivers with great modesty and distinctness'.