Part III. The universe of law

8. Cartesian cosmology

A physics of the universe

Although Aristotelian philosophy had been the subject of attack for nearly two centuries, in 1635 it still stood firm. The strongest argument in its favour, however, was simply the lack of an alternative. Especially in teaching, it was felt that a clear systematisation of knowledge was needed to introduce students to the world of learning. Aristotelianism was the only such system available.

Aristotelianism collapsed in the end, not by a slow crumbling under the accumulation of its problems, nor by gradual adaptations until it had simply grown unrecognisable. Aristotelianism was finally brought down by a deliberate attack. Descartes designed an all-embracing philosophical system which established itself as a viable alternative to Aristotelianism. In most of the literature on Descartes, emphasis is laid on his work in metaphysics and methodology. However, it can be defended that these philosophical ideas served mainly as a legitimation of his new physical world-view. [1]

In the end, Descartes views were compelling because they offered the new intellectual framework into which the many discoveries and insights of the previous century could be fitted. It can be argued that, for instance, Harvey's theory of the circulation of the blood or Sanctorius' static medicine took on their modern 'scientific' shape only under the influence of Cartesian philosophy. Galileo's discoveries had been anomalies in the Aristotelian cosmos. In Descartes' world, they appeared as the logical consequences of his general view of nature. Likewise, Copernicanism was transformed from a mathematical theory of the heavens into the application of general physical principles to the phenomena of the solar system. Copernican cosmology had always been handicapped because it ran counter to accepted ideas on the universe.

[1] Gaukroger (1995); van Ruler (1995). The literature on Descartes is of course immense. I restrict myself to the most relevant sources.

Descartes finally changed this. Thus, it was Cartesianism which turned the heliocentric theory into an acceptable and indeed dominant idea. [2]

This is not the place to discuss Descartes' ideas in general, but a brief overview of his ideas on the system of the world cannot be dispensed with. These ideas were put forward mainly in his *Principia philosophiae* (1644). An earlier work on the same subject, *Le monde*, remained in manuscript. Anyhow, it should be emphasised that these ideas were compelling only because they were part of a larger whole. Descartes claimed that his physics had a mathematical character. Mathematical reasoning, not the unreliable testimony of the senses should be our guide to truth – an argument which could well have been framed with the Copernican debate in mind. Descartes maintained that he could prove the basic constitution of the world in a rigorous way from some basic 'axioms' or principles. Descartes himself did not capitalise on the analogy between the physical world and the world of mathematics, but some of his followers did, as we are to see shortly.

Descartes regarded nature as uniform. This entailed a universe which was in principle without limits and without a centre. Neither the sun nor the earth could be allotted a special place in it. The Aristotelian world with its many different spheres and regions was simply incompatible with the world-view propagated by Descartes. On the other hand, Copernicus' world, with the sun in the centre as on a royal throne, would also not do. In Descartes' universe, all the stars were suns. Each star was the centre of a vortex. In the case of the sun, this vortex carried the planets around the sun. The planets in their turn were the centre of other smaller vortices, carried along with them. These secondary vortices caused the planets to rotate on their axis. They also carried with them the planets' moon(s), if they happened to have such. [3]

The various celestial bodies were in a sense equivalent. Like Girard and Van der Veen before him, Descartes felt that over the course of time they could be transformed into each other. The vortices were in a state of equilibrium with their surroundings, but if circumstances changed, they could collapse. Stars constantly became obscured by matter as it coagulated, as evidenced by sunspots. Normally, grosser matter was ejected, but when there was too much of it, the star's surface would be obscured and the star would not be able to keep its vortex turning. In this case, the vortex would collapse

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[2] The pivotal role Cartesianism had in many cases in the acceptance of heliocentrism has been recognised before. Brockliss (1990) makes a rather general case for France. In Sweden, according to Sandblad, geocentrism lost favour in the course of the second half of the seventeenth century because of 'the general Cartesian tide of the time': Sandblad (1972) 265 and *passim*. See also Vanpaemel (1995) 116-118, on Louvain, and Moesgaard (1972) 134-140, on Denmark.

[3] For a discussion of Descartes' theories, see Aiton (1972) 34-58.

and the star would be absorbed by a neighbouring vortex. Depending on the circumstances, it would move either to the near centre of its new vortex and become a planet, or to its periphery and become a comet, traversing space at the edge of the various vortices. According to the Cartesian hypothesis, the earth itself had come into being in this way, as a star which had been obscured and absorbed by the vortex of the sun. Descartes himself stated that this theory was a mere working hypothesis which could explain the phenomena, but that it could not be true as it was not in accord with the story of the Creation. [4] One may reasonably doubt whether this was his real opinion, or a matter of caution with the fate of Galileo in mind. His followers generally preferred to forget about this qualification.

A convincing argument in favour of Descartes' vortex theory was that it could also give a plausible explanation of the tides. It had long been remarked that the movement of the sea was synchronous with the course of the moon (although Galileo rejected this, apparently because he found it smacked of occult forces), but the exact mechanism was unclear. According to Descartes, the tides were caused by the pressure of the vortex around the earth. As the vortex had to pass through the relatively narrow space between earth and moon, its sideways pressure increased, pressing down the sea level. At the same time, it slightly pushed the earth aside, increasing the pressure of the vortex, and hence lowering the sea level, on the other side as well. The waters naturally flowed towards the other sides of the earth. As the moon's orbit was not circular but oval, the distance between moon and earth – and thus the space through which the vortex had to pass – varied over time. The narrower the opening, the higher the pressure of the vortex and the lower the sea level would fall. Thus even the alternation of spring tide and slack water could be explained by Descartes' theory. [5]

There is one final element which should be explained in some detail, as it directly affects Descartes' interpretation of Copernicanism. This has to do with his theory of motion. Descartes rejected the Aristotelian absolute distinction between motion and rest and upheld a relativistic definition: motion can only be defined as such with respect to something else. For a philosophical definition, however, he felt such a random choice would not do. The motion of an object, then, should be defined with respect to the object's immediate surroundings. A ship drifting on a swiftly flowing river should be said to be at rest, as it is not moving with respect to the water. Applied to the case of the earth, it is moving with respect to the sun. But if we are to answer the

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[4] *AT*, VIII-1, 99-100, 203.
[5] *AT*, VIII-1, 232-238.

question of the earth's motion or rest in a more philosophical way, we must look at its immediate surroundings. Now, the earth is drifting in a large vortex of celestial matter, just as the ship is drifting in water. As the earth is simply drifting, it will not be moving with respect to the vortex. Properly speaking, therefore, the earth is at rest. The argument seems deliberately framed to attenuate religious misgivings about the Copernican system. It is hard to see why otherwise Descartes would have stated this so explicitly. Indeed, it is introduced for the first time in *Principia philosophiae*.[6] When writing *Le monde*, Descartes had not yet contemplated the problem. Still, the argument, without being flawless, follows quite logically from Descartes' general ideas on motion.

Under the influence of Descartes' ideas, many people came to regard the theory of the annual and daily motions of the earth as an established fact, rather than as an explanation which was plausible at best and anyhow open to discussion. Heliocentricity seemed to follow inevitably from his view of nature. How this came about is analysed in the following sections. Three figures, all advocates of Copernicanism, will be discussed in some detail. All three formulated their ideas in a clear and personal way. Two of them were minor figures who at an early date became convinced Cartesians. The third was one of the greatest scientists of the age, and who showed the stamp of the new physics throughout his career. In all cases, their Copernicanism appears to follow from the general ideas which had been forced upon the age by Descartes.

Daniel Lipstorp: mathematics as philosophy

Daniel Lipstorp made a great contribution to the identification of Cartesianism and Copernicanism. Lipstorp, a German, was born in Lübeck in 1631. He studied for some time at Rostock University, where he obtained the title of master in 1651, and at Leiden, where he matriculated on 4 July 1652. In 1653 he went to Weimar as a court mathematician. In 1656 he returned briefly to Leiden to matriculate (26 September) and to be awarded his doctorate in law (2 October). His further career carried him to Uppsala and The Hague, and then back to Lübeck, where he died in 1684.[7]

During his first stay in Leiden, Lipstorp published a *Specimina philosophiae Cartesiana* (1953) with a sequel called *Copernicus redivivus*: 'Copernicus revivified, or On the true system of the world'. The *Specimina* consist mainly of a discus-

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[6] AT, VIII-1, 89-91.
[7] Günther in: *Allgemeine deutsche Biographie*, XVIII (Leipzig 1883) 746.

sion of air, describing among other things various pneumatic instruments. Pertinent to our subject are the two introductory chapters, which discuss generalities. In the first – 'On the certitude of Cartesian philosophy' – Lipstorp argues that one should demand mathematical proof not just in mathematics, but also in physics. Of course, it is only Cartesian philosophy which can give this kind of proof.[8] In the second chapter, he shows how one should take this. Here, he gives Descartes' rules of motion, demonstrating them in – what he claims to be – a mathematical way. Lipstorp starts with a number of definitions and postulates. These are followed by twelve 'axioms or general rules', which comprehend Descartes' three laws of nature as well as some other generalities Descartes had presupposed rather than formulated; for instance, some rules concerning the transmission of a quantity of movement from one body to another. These axioms are followed by nine 'theorems', which correspond to Descartes' nine rules of percussion.[9]

Copernicus redivivus, the second part of the book, is a vigorous defence of the Copernican world system. It was largely based on a series of six disputations Lipstorp had held the previous year (1652) at Rostock University (Germany): 'Physico-mathematical discourse on the Copernican system of the world'. In these disputations, he had shown 'that that Pythagorean opinion is not so improbable and paradoxical as is commonly reputed, but that, as far as it is defended by mathematical experiences taken from heavenly appearances and by physical arguments, it is in its way preferable to, and more probable than, the Ptolemaic system.'[10] Still, even when defending that Copernicanism was not contrary to natural reason, in 1652 he had rejected it in the end on biblical grounds. The second half of the sixth disputation was largely devoted to a discussion of the arguments from Scripture. Scripture, he stated, clearly stated that the earth stood still, and this argument should be decisive. Although discussing the Copernican counter-arguments in some details, they failed to convince him.

His position appears to have changed by the time he wrote *Copernicus redivivus*. Although largely based on the earlier work, it has been reworked up to the point of being unrecognisable in many places. The whole work is divided into two books. In the first, Lipstorp, after some general remarks on scientific progress, starts with a rather traditional account of the theories of Copernicus and their history. In the fourth chapter, he explains Descartes' idea of the 'true motion' of the earth, that is to say, that it rests in the celestial matter. The other chapters are also rather traditional. Lipstorp discusses the various systems

[8] Lipstorp (1653) 1, 1-27.
[9] Lipstorp (1653) 1, 28-58.
[10] Lipstorp, disp. Rostock 1652, title of the separate disputations.

which try to compromise between Ptolemy and Copernicus, in particular the one by Tycho Brahe, and points to the various absurdities of the Ptolemaic system. The second book is mainly a rehearsal of all the arguments put forward against the Copernican system, along with their refutation. The eighth chapter, the final one, deals with the arguments from Scripture. Although these are not our main subject in this chapter, it is important to note that Lipstorp had completely revised his earlier opinion. Whereas one year earlier he had deemed the scientific arguments insufficient to decide that the biblical passages should not be taken in a literal way, in *Copernicus redivivus* he quite emphatically argued that Scripture cannot decide questions of mathematics or knowledge of nature.

As said, Lipstorp presented his defence of Copernicanism together with a work on Cartesian philosophy. So, how far was his Copernican conviction in 1653 based on Cartesian philosophy? On the whole, the Cartesian element in *Copernicus redivivus* is not very marked, apart from the fourth chapter of book one. Partly, this is undoubtedly because it concerns a reworking of an earlier, non-Cartesian work. Besides, Lipstorp of course had had a largely non-Cartesian education, and it seems clear that originally he had entered the discussion on the system of the world because of his interest in mathematics, not because of Cartesian physics. His work is rather an exercise in learning. Instead of developing an argument of his own, he mainly discusses those of others. He clearly likes to show off his erudition and refers to as many famous and obscure authors as he possibly can. Characteristically, he closes the book with a phrase in Arabic, 'It has been finished with the help of God, all glory be to Him!', a common conclusion of Arabic works.[11]

Still, his contemporaries had little doubt. To the Leiden minister Du Bois – one of the most prominent clerical opponents of Copernicanism in the Dutch Republic – Lipstorp served as a living example of the pernicious effects of Cartesian philosophy. He had seen the six earlier disputations, and knew that in the first five and the beginning of the sixth, Lipstorp, using natural reasons, argued in favour of Copernicus; but that, when he finally arrived at the arguments from Scripture, he abandoned his pro-Copernican stance. That, Du Bois thought, is how it should be: natural reason yielding to revealed truth. But then he found that as a Cartesian, Lipstorp thought he could dismiss the arguments from Scripture. In Du Bois' view, this served to prove that Cartesianism was undermining religion.[12]

In the preface to the *Specimina*, Lipstorp himself is quite explicit. In 1652, he

[11] With thanks to Dr J. Hogendijk, Utrecht, for the translation and explanation.
[12] Du Bois (1655) b, 25-27.

had not been convinced of the truth of the Copernican system; since then, however, he had dedicated himself to mathematics, optics and Cartesian philosophy at Hamburg under the guidance of Johann Adolph Tasse (Tassius) and at Leiden under Frans van Schooten. While studying optics, he came to admire Descartes. He then found that in Descartes' system, all objections to Copernicanism disappeared.[13] Of course, we have to regard such a 'spiritual autobiography' with some caution. It is not inconceivable that Lipstorp remodelled his life after a convenient model. One might wonder whether Lipstorp was not already a convinced Copernican at Rostock, and that it was outward pressure rather than inner conviction which led him to the cautious conclusion of his disputations. In that case, his change of mind would have been only apparent and not caused by philosophical considerations.

This matter is hard to decide. Lipstorp was not a die-hard opponent of Copernicanism in 1652, and if he was not already convinced of its truth he must at least have been pleased to find a reason to become so. However, if Lipstorp thought it expedient to present his Copernicanism as an outcome of a conversion to Cartesianism, that means that such a presentation made some sense. Cartesianism could be seen as the foundation of Copernicanism as a real, physical theory, instead of a mere mathematical hypothesis. How did Cartesianism, in his view, strengthen the Copernican hypothesis? One might suppose that Descartes' theory of the 'real' motion of the earth, which after all was posited prominently in his book, played some part. However, it is striking that this theory is not used in the final chapter to reconcile the difference between the physical model and the biblical text. Apparently, Lipstorp had other, better reasons not to doubt the Copernican system.

Most probably, this was the mathematical structure of Cartesian philosophy itself. His Cartesian conviction is summarised by the sentence: 'Mathematics itself is the true and best philosophy'.[14] What he meant by this is shown by his discussion of the elliptical shape of the planetary orbits. Credit for demonstrating this elliptical shape he allotted to Boulliau, not to Kepler, who had shown it (in the case of Mars) only by calculation. To Lipstorp, such a proof clearly was not enough. Boulliau had demonstrated it 'from general and known dispositions of motion.'[15] The theory of elliptical orbits is not in Descartes, nor in most later Cartesian authors. Lipstorp himself speaks of it only in his preface. Still, the passage shows what he considered vital for a scientific theory. In this respect, we should not regard *Copernicus redivivus* in isolation from the preceding *Specimina*, with its mathematical presentation of

[13] Lipstorp (1653)a, preface.
[14] Lipstorp (1653)a, preface.
[15] Lipstorp (1653)b, preface.

Cartesian physics. Cartesianism set new, mathematical standards for theories on the world. Many older theories were dismissed in this way, but for theories which answered these, Cartesianism claimed mathematical – that is, absolute – truth.

Christophorus Wittichius' decisive argument

Another German who studied in the Dutch Republic and was won over to Cartesian philosophy was Christoph Wittich (Christophorus Wittichius). Wittichius was a theologian who, after professorships at Herborn, Duisburg and Nijmegen, ended his career as professor of theology at Leiden. In 1653, the same year Lipstorp published *Copernicus redivivus*, Wittichius published in Amsterdam two dissertations (*Dissertationes duae*), which had earlier been defended at Duisburg University under his presidency. These disputations are primarily a theological work, concerned with biblical exegesis. Wittichius' main aim is to demonstrate that the theory of Copernicus is compatible with biblical revelation. As such, the work will be more fully discussed in a later chapter, on Copernicanism and biblical exegesis. At this point, it is important to note that the confidence with which Wittichius tackled the issue was founded in Cartesian physics.

That Cartesianism was really the foundation of Copernican cosmology was made clear already in the introduction: 'About the most important of the physical propositions of Descartes, still fouled by fools' mud, concerns the annual motion of the earth around the sun and the daily motion on its axis. Descartes, having expounded this hypothesis according to Copernicus, who had resuscitated it after it had long remained buried, has defended it by means of a very certain and evident mathematical proof which no one (except those who do not understand it) has so far been able to refute; nor will anybody ever be.' It was this new Cartesian insight which moved Wittichius to discuss the question of Copernicanism and the Bible afresh: 'Until now, Copernicus' defendants were not able to demonstrate the theory of the double motion of the earth in such a clear way, as Descartes has done after having laid surer foundations of physics.' [16]

The first of the two dissertations is completely devoted to biblical exegesis, which does not interest us here. It is complemented, however, by the second dissertation, which is primarily a physical work. As the title states, it 'deals with the disposition and order of the universe as a whole and of its main bodies, and defends the opinion of Descartes on the true rest and true motion

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[16] Wittichius (1653) praefatio.

of the earth'. First of all, Wittichius discusses the size and form of the universe. As humans do not know the outer limits of the universe, we have to take it as indefinite. As a consequence, we cannot speak of a centre of the universe (a centre can only be defined in relation to a circumference). Of course, we can speak of a centre of the movement of the planets, 'centre' to be taken here in a physical, not a geometrical sense. This centre is the sun: both Copernicus and Tycho agree on this point (Ptolemy is no longer a viable alternative). Only the earth has so far remained a matter of dispute. [17]

Wittichius next turns to an elaborate discussion of the world's system. This part is little touched by Cartesianism. Despite his declared intention to leave most arguments untouched, Wittichius' argument is mainly a rehearsal of a large number of ancient and modern authorities supporting heliocentrism. Most attention is paid to respectable, but in modern eyes highly spurious, ancient authorities such as Pythagoras and Numa Pompilius. Cartesian physics turns up only in the fourth chapter, where Wittichius defends Descartes' definition of motion against his opponents.

In the fifth chapter Wittichius finally presents his 'mathematical' proof of the earth's motion. As he explains, he will not refer to simplicity, harmony or the velocity of the heavens, but will use a 'demonstrative and most evident argument taken from our philosopher.' [18] This argument appears to come down to just a summary of the relevant passages in Descartes' *Principia philosophiae*. As Lipstorp did at about the same time, Wittichius put them in a synthetic-mathematical form. As he had explained in the preface, Descartes' physics is a coherent system, in which one cannot understand the later propositions without having understood the earlier ones – he explicitly makes a comparison with the work of Euclid. So, he is compelled to start from first principles. He cannot discuss all of Descartes' physics, of course, but a clear idea of Descartes' idea of motion is essential. [19]

Wittichius gives Descartes' theory in the form of 28 propositions. The first is that all corpuscles in the world are made of one and the same kind of matter. The second is the impossibility of a vacuum. This entails that any displacement of a corpuscle affects the corpuscles in the environment as well. From this, the theory of vortices is deduced and hence follows the whole of Descartes' cosmogony (which Descartes himself had presented as a mere hypothesis). Finally, he arrives at the motion of the earth in the solar vortex, wherewith the truth of the Copernican system has been proved. [20] Wittichius, it

[17] Wittichius (1653) 171-172.
[18] Wittichius (1653) 225.
[19] Wittichius (1653) praefatio.
[20] Wittichius (1653) 226-244.

seems, regarded this as a definitive argument – as mathematical arguments should be, of course. Some years later, he returned to the subject after his two dissertations had been the target of vehement criticism. Although much more elaborate, this new work is really just a repetition of the former; so, we re-encounter exactly the same 28 propositions. [21]

Wittichius, then, at the same time and in roughly the same way as Lipstorp, found in Cartesian philosophy a 'mathematical proof' of the motion of the earth, convincing up to the point that it should decide a theological debate. Both, be it in different ways, reformulated Descartes' principles as a mathematical argument. How this coincidence comes about is difficult to say. One suspects the influence of academic teaching at Leiden, but clear indications are lacking. Nor would their cases remain unique. A work which would undertake the same kind of reformulation in a more systematic and comprehensive way is Spinoza's *Renati des Cartes principiorum philosophiae pars I & II, more geometrico demonstrata* from 1663. Later in the century, of course, the '*mos geometricus*' became a rather popular argument for non-physical discourse as well, Spinoza's *Ethica* taking pride of place among the literature of this kind. This geometric way of reasoning seems to have its origin in the mathematical reformulations of Descartes' physics. [22]

Out of Descartes: Christiaan Huygens

The significance of Descartes' ideas for the reception of Copernicanism was not limited to minor philosophers and theologians, nor to Cartesians in the strict sense. Descartes' fundamental ideas determined the scientific discussion of the second half of the seventeenth century. They also dominated the thought of the truly great scientists of the age. In order to demonstrate this, we shall finally have a look at Christiaan Huygens.

Huygens grew up at a time when Cartesianism was much in vogue. His father was the diplomat and virtuoso Constantijn Huygens, one of Descartes' main protectors in the United Provinces. He obtained his main scientific education from the mathematician Frans van Schooten, a close friend and admirer of Descartes. Still, his relation to Cartesianism remained ambiguous. In his youth, Huygens was much impressed by Descartes' system, but over the course of time, he came to acknowledge various weaknesses in it, particularly in its physics. Huygens was too much of a mathematician and too little

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[21] Wittichius (1659) 80-339; for the 28 propositions, see 241-339.

[22] As is well known, Descartes himself had already put his proof of the existence of God and the distinction between soul and body in the form of a mathematical argument, at the suggestion of Mersenne in the latter's objections to Descartes' *Meditationes de prima philosophia*. Cf. Dear (1995).

of a philosopher to feel truly at home in the Cartesian world. Rather, he continued the tradition of men like Kepler and Galileo in their mathematical description of nature. If Descartes aimed at supplanting Aristotle, Huygens figured as a new Archimedes.

Still, Huygens owed a lot to the new physics as put forward by Descartes. His critical stance can be largely explained by the fact that Cartesianism was to him a point of departure, not a new theory which solved old questions. It offered him a frame of reference for his scientific investigations. To Huygens, the system of the world was no longer a matter of debate. The truth of the Copernican system was simply an established fact. Huygens never bothered to discuss the relative merits of the Copernican, Ptolemaic and Tychonian systems. Instead, he pondered the various alternatives within Copernicanism. In a letter written in 1656 to the Polish astronomer Hevelius, he explains his preference for Kepler's elliptical orbits, above Copernicus' construction by means of epicycles. [23] Only when directly attacked on his Copernicanism did he comment on the relative merits of Tycho and Copernicus: 'Which of these two I apply hardly matters as far as phenomena are concerned. But the truth of the matter is explained only by following Copernicus.' [24]

Copernicanism, then, was an integral and important part of Huygens' world-view, self-evident up to the point that it needed no special defence. Still, there are also some instances wherein he clearly gave his stance on the subject. Huygens was aware that Copernicanism had not been accepted generally and he thought the matter important enough to propagate it when the occasion presented itself. The points where Huygens' work is part of the history of Copernicanism and cosmological theory are his *Systema Saturnium* and his *Kosmotheoros*. As a third point, one might mention the Copernican planetary he designed and built in 1680-1682. In this case, his primary aim seems to have been to construct an accurate planetary, which could be used for predicting planetary conjunctions. It must have seemed only natural to him to use a Copernican model. But at the same time it also had a didactic purpose, as Huygens himself acknowledged. [25]

In the case of the *Systema Saturnium*, the situation is somewhat different. Huygens earned his first public success with his telescopic observations. In 1655 he discovered a moon of Saturn, which later was named Titan. It was the first really new discovery in the solar system since the time of Galileo, and as such was a scientific sensation of the first order. At the same time, Huygens also gave the first correct interpretation of the curiously varying shape of

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[23] Huygens to Hevelius, 25 July 1656. *OC*, I, 463-464 (no. 318).
[24] *OC*, XV, 459 (*Assertio systematis Saturni*, 1660).
[25] Seidengart (1982) 210.

Saturn as observed by a telescope: the planet was surrounded by a ring, slightly inclined with respect to the plane of the ecliptic. These discoveries were momentous in their own right. But Huygens also perceived that they offered additional evidence for the truth of the Copernican system. Already in 1656, in a letter to van Schooten, he called them a 'confirmation of the Copernican system: another earth, another moon'. [26] In the official publication, *Systema Saturnium*, which appeared a few years later (initially, he had only announced his discoveries in a four-page pamphlet), the point was more explicitly made. In the dedication to Leopold de Medici, prince of Tuscany, Huygens emphasised that his system of Saturn confirmed most strongly 'that beautiful general order of the world, which has its name from Copernicus'. The fact that Saturn proved to be so akin to our own earth, having, like the earth, one single moon (instead of four, like Jupiter, or none at all, like the other planets), and being, as apparent from the position of its ring, slightly inclined with respect to the ecliptic (again, just like the earth), made it most probable that the earth was just a planet. [27]

So, Huygens used his *Systema Saturnium* to take sides in the Copernican debate, which was still going on in Europe and had just reached its peak in the Dutch Republic, as we will see in Part IV. In fact, Huygens was ready to go out of his way to strengthen the case of Copernicanism. One might ask how he could have been so sure that Saturn had only one moon. In fact, before the seventeenth century was over, Cassini would discover another four. Huygens had apparently considered the rejoinder and countered it in advance by means of an argument that has rather bewildered most historians who have dealt with it. [28] As he explained in his dedication, it seemed improbable that more planets (moons included) would be discovered, as his latest discovery had brought the number of secondary planets to six (one moon of the earth, one of Saturn, and four of Jupiter), which was equal to the number of primary planets. That is, both kinds of planets equalled the perfect number of six (in mathematics, a 'perfect' number is a number of which the addition of the factors gives the number itself: $1 + 2 + 3 = 1 \times 2 \times 3 = 6$.) This could be no coincidence, but apparently had been ordained on purpose by the all-wise Architect. The use of this kind of number mysticism to explain the frame of the universe had of course been quite common in the first half of the seventeenth century, but it is astonishing to encounter it with Huygens, who had been brought up with the new mechanical philosophy. Indeed, it has no parallel anywhere else in his work, nor does he repeat it to a more scholarly corre-

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[26] Huygens to Van Schooten, 10 March 1656. *OC*, I, 389 (no. 269).
[27] *OC*, XV, 215.
[28] I.B. Cohen (1978).

spondent. His prime reason for introducing it here was probably rather ad hoc, viz. to strengthen his argument of the analogy between Saturn and the earth.

The second argument, too, is rather far-fetched. Huygens found that Saturn's ring was inclined to the ecliptic at a constant angle. As this was more or less similar to the constant inclination of the earth's axis, he *assumed* that the inclination of Saturn should be the same as the inclination of the earth, i.e. 23.5 degrees. [29] Proving from this assumption the similarity between Saturn and the earth is something of a circular argument, of course. Still, this was not just an argument for the good of the cause. Even after Huygens realised that his theoretical values did not match observations, he sought the fault with other magnitudes (such as the width of the ring) rather than with the angle of inclination itself. It was many years before Huygens was ready to abandon his 23.5-degree angle for Saturn's inclination in favour of a more realistic value of 31 degrees. [30]

Thus, it appears that Huygens' interpretation of his discoveries was guided by a strong intuition of the similarity between the earth and Saturn. From this analogy, he argued the truth of the Copernican system. The analogy, of course, was based in a belief in the basic similarity of the celestial and terrestrial worlds. This was a deep-rooted conviction Huygens entertained not only in his youth, when he wrote *Systema Saturnium*, but also later in life. The last work he accomplished was his *Kosmotheoros*, which was published posthumously in 1698. Huygens' subject here is the probability of life on the celestial bodies. Most modern historians have regarded it as scientifically uninteresting, rather as some kind of playful entertainment, a cosmological fantasy. [31] But Huygens obviously did not think of his book as a work of the imagination. He referred to it shortly before his death: 'At present I am working on some philosophical subject.' [32]

Huygens indeed pretended to give a logical argument. Our observations teach us that the planets are basically the same as our earth, and the stars to our sun. We may surmise that they will be similar, too, in those respects which defy observation up to now. Consequently, we are allowed to draw conclusions about the different planets on the analogy of our own earth. Hence the

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[29] *OC*, XV, 309 (French translation 308). Cf. van Helden (1980) 153.

[30] *OC* XV, 476-477, 483-484. See for the whole episode (and a sequel): D'Elia (1985) 99-122, who also points out the significance of Huygens' discoveries in corroborating the truth of the Copernican system.

[31] *OC*, XXI. The work is discussed by Seidengart (1982). See also Snelders' postface in the reprint of the Dutch translation (Huygens 1754).

[32] Huygens to Gregory, 19 Jan. 1694, in: Vermij and van Maanen (1992) 512, 523.

seemingly paradoxical but in fact very apt title: 'Conjectures on the heavenly earths'. The argument from analogy led Huygens to suppose that life on the planets is similar to that on earth. After all, there is no reason why there should be a greater difference between various planets than between various continents. Consequently, the animals on other planets are built like those on earth, procreate like those on earth, and some of them will be intelligent, just as on earth. The latter's intellectual and spiritual life will be akin to that of man, and they will live in a similar society.

It is easy to see that the whole book is built upon one basic idea: the universality of nature. In the second part of the book, Huygens deals with the stars and the various planets in a more rigorous astronomical manner and gives information about their size, distances and appearances, and what it would be like to live on them. Nature is the same, always and everywhere. The differences between the sun and the other stars are differences of size and measure, not of principle. The same holds for the differences between planets. Life itself, even intelligent life, has no specialised position in nature. Huygens just drew a leading idea of the scientific revolution to its (seemingly) logical conclusion.

The argument appears to have appealed to contemporary readers. Within a few years, the book had been translated into English, French, German and even Russian. As for the Netherlands, it was enthusiastically reviewed by the journalist Petrus Rabus, who shortly afterwards, in 1699, published a Dutch translation. In part, the book will have pleased because of its second part, an elementary introduction to the universe. But its first part was approved, too. In a poem appended in front of his translation, Rabus praises Copernicus for establishing the fact that every planet, 'in vastness and size, equals our earthly living place'. He endorses Huygens' view that on the planets would live 'animals, no lesser in soul and reason than you. Or would the intellect, which teaches us to ascend gradually to the sciences, have been given only to us, and to no others? Such has never been written. Reason itself denies it.' [33]

It is this basic belief of Huygens in the universality of nature which forms the foundation of his unqualified support of Copernicanism. If there is no basic distinction between heaven and earth, between sublunary and superlunary nature; if the universe is indeterminate and has no centre, then no body occupies a special place in the world. The sun is but a star, and the earth but a planet. This belief Huygens clearly owed to Descartes. Copernicanism received its ultimate support from Descartes' view of a geometricised nature.

[33] Huygens (1754).

It is this background to Cartesian philosophy which makes Huygens' work different from that of Kepler or Galileo.

New theories of motion

It seems that the principles of Cartesian physics indeed were a turning point in the reception of the Copernican system. Copernicanism not only fitted in with the view of the universe put forward by Descartes, but was even felt to be a necessary consequence of the constitution of nature. First there was the new view of the universality of nature, which had been in the air since Galileo's discoveries but was now used as a starting point for natural philosophy. And second, this new natural philosophy claimed a mathematical character, and hence mathematical exactness.

It was such general changes in world-view rather than more specific arguments which won most people over. After all, the old arguments against the motion of the earth were as valid as ever. One might presume that the acceptance of the motion of the earth was facilitated by the waning of the Aristotelian concept of motion, and its replacement by the modern, mathematical view of motion in the work of Galileo and Huygens. The concept of inertia offered a solution for the common objections against the motion of the earth, wherein a cannonball, a bird or anything which was above rather than on the earth was supposed to remain behind if the earth moved. Theoretically, this solution may have been available. In practice, however, the role of these new insights appears to have been very limited. It is possible to find the concept of inertia fully developed in Descartes' writings; [34] however, he appears unaware of its full consequences and his ideas on motion are actually rather inconsistent. His followers interpreted his work in a variety of ways and their ideas of motion (or rest) as a rule place these concepts in the realm of metaphysics rather than mathematical physics. [35] In understanding the motion of the earth, these ideas were of little help.

The way the theory of inertia was ignored can be illustrated from the theory of ocean currents. An ancient theory attributed the ocean currents to the general motion of the world (that is, the universe) from east to west. Because the heavens turn round in 24 hours, the elements of air and water still had a remnant of this movement left, thus creating the trade winds and ocean currents. Only the element of earth stood motionless in the centre. This theory is propounded (for the case of ocean currents) in an anonymous Latin manu-

[34] *AT*, VIII-1, 54-55.

[35] Vermij (1996) 277-281. Ruestow (1973), *passim*.

script on astronomy, which dates from after 1610 and seems to be of Dutch provenance. In order to calculate the dimensions of the earth, the author uses the difference in latitude between Franeker and Deventer. He probably was teaching in one of these towns. So, in this case ocean currents were seen as supporting the movement of the heavens and the rest of the earth.[36]

With the advent of Copernicanism, this theory was simply reversed. According to one Dutch author, the ocean currents (from east to west) in the tropics are caused by the daily rotation of the earth, 'because the fluid water cannot follow the earth apace, but continuously lags behind.'[37] (Still, the wind may also contribute.) This theory is not found in the work of Descartes, whose ideas on motion were probably too sophisticated. It was defended, however, by Galileo (in the case of trade winds) and Kepler (for ocean currents).[38] In the Dutch Republic, it was first upheld by Descartes' follower Regius.[39] Another Cartesian who upheld the theory was the French philosopher Régis; his ideas on the subject appeared in Dutch in 1700.[40] The argument appears to have been quite popular, not only among academic philosophers, but also among mathematical practitioners.[41] Their Copernicanism thus went hand in hand with a traditional idea of motion.

Huygens, however, knew better. But in his case, it is particularly evident that the plausibility of the Copernican system was not a result of the better understanding of the physical processes involved, but vice versa. Taking the Copernican system for granted, Huygens used this presupposition to solve questions in physics. Galileo had argued for the Copernican system on the ground that the motion of objects on earth should be seen relative to the earth; for an observer on earth, they appear the same whether the earth is moving or not. Assuming the basic soundness of this idea, Huygens used it to gain a better insight into the mechanics of motion. By applying it to percussion phenomena, he found the rules by which they were governed and incidentally showed the fallaciousness of Descartes' rules. Thus, it was not by applying the new rules of mechanics that the old arguments from projectiles etc. against the motion of the earth were refuted; by assuming that the

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[36] Utrecht UL, VI G 14, f 26[v]. On f 24, the author refers to a proof which '*in demonstrationibus nostris ad Euclidem tradidimus*'. On the explanation of ocean currents, cf. Burstyn (1966) 170.

[37] Van der Moolen (1702) 23-24.

[38] Burstyn (1966) 170.

[39] Regius (1646) 93.

[40] Hartsoeker (1700) 241-242. (The translator, Ameldonk Blok, expanded the book from other sources.)

[41] Apart from van der Molen (1702), mentioned above, de Graaf (1659) 15 also explains that the daily rotation of the earth results in a continuous motion of the waters from east to west.

earth moved and that thus the ancient objections had to be fallacious, new rules of mechanics were found.[42]

Other Cartesians and Copernicans did not even feel the need for a new theory of motion. Huygens' rules of percussion met with incredulity on the part of his teacher Van Schooten, who could hardly believe that Descartes could have erred in this matter. And most Dutch Cartesian natural philosophers ignored Huygens' inventions completely.

[42] Mormino (1993) 10-18.