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TRAITS OF ANCIENT NATURAL PHILOSOPHY IN OTTO VON GUERICKE'S WORLD OUTLOOK

The shaping and the evolution of Western European culture, occasioned by a great diversity of influences, has been taking place within the last twelve centuries. Multilayered superpositions occurred, leading to the formation of spheres susceptible to new configurations effected by some kind of contact metamorphism. Subsequent to the christianization of Western Europe at the time of Charlemagne, and following what is called the first, or Carolingian Renaissance, twice during the ensuing millennium there set in an enduring influence of Greek natural science and mathematics upon Western European thinking.

For the first time, it was during the 12th century that there grew an appreciation of Greek literature, which had been scarcely known by then. This came about both directly, through Byzantium and Sicily, and indirectly, in a roundabout way through Spain and Chartres. At that time Western Europe came to know — apart from Ptolemy's writings, such as his *Optics* — Euclid and Proclus and, in particular, Aristotle's writings on natural sciences. Somewhat earlier, the full scope of the logical writings of Aristotle had been accessible to scientists of Western Europe, and all this knowledge contributed to the evolution of Scholasticism, and finally to its full maturation at the time of Albertus Magnus and Thomas Aquinas. The late Scholasticism saw critical disputes on separate topics and, at times, on controversial theses in Aristotle's doctrine; shortly afterwards, these polemics paved the way for the evolution of new concepts of natural sciences.

It may be considered fortunate for this evolution of natural science, that familiarity with Aristotle's natural philosophy was gained at this relatively late period. To the adherents of the mature Scholasticism, the doctrines of Plato, Aristotle or the Stoics, in contrast with the teachings of the Fathers of the Church, had ceased to be forms of world outlook competing with Christianity. Meanwhile, the fundamental beliefs of the Christian Church had been stabilized and, apart from the teachings of the Epicureans, the concept on natural science promulgated by the Academy, by the Peripatics and by the Stoics were fully consistent with Christian beliefs. As a rule, any divergences were candidly discussed, and discourses of this kind were the more welcome, because they offered the opportunity of displaying adroit dialectics and exhibiting extensive literary knowledge.

Since the 13th century, Western European scientists used to render an account on natural science and its individual topics to themselves and to their contemporaries on the basis of Ptolemy's geocentric universe, and a Christian version of Aristotle's doctrine supplementing it. By the revived memory of Rome's ancient greatness as well as the renewed interest taken in the artistic and cultural heritage of classical antiquity and, after Constantinople's fall in 1453, the intensified attention paid in Italy to Greek writings, it was not only Plato's philosophy alongside with the doctrine of Aristotle that acquired a new significance. Also reawakened was the knowledge of other cosmological tenets of ancient times and, first of all, the cognizance of the writings of the great Greek mathematicians, especially of Archimedes, and of the Alexandrine „technicians," with Heron of Alexandria as a typical representative. However, in the renewed confrontation of antiquity and Western European science it was not only the leading clergymen and their noble protectors who endeavoured to comprehend the rather intricate—occasionally—purport of these ancient writings. The remaining classes of the population also became much interested in these intellectual happenings. It was therefore unavoidable, that important men of commerce, capable craftsmen and navigators started comparing, first out of mere curiosity and, later on, in a critical, even sceptical mood, the experience gained in their own mode of life with the novel book knowledge. In this manner the ocean roamings of the Portuguese and the Spaniards, the experience acquired by miners and smelter men, armourers, compass-makers and pharmacists—all contributed to the shattering of the traditional notions on nature and universe no less than did the resumed studious readings of Greek authors on the subject of a probable axial revolution of the globe or, even, of the earth's circular motion around the sun. Apart from efforts made to attain the urgently needed reform of the calendar, literary sources as mentioned above stimulated the Frombork canon Nicolaus Copernicus to evolve his novel heliocentric world system, published in the year of Copernicus' death under the title *De revolutionibus orbium coelestium libri VI.*

After this book had appeared in 1543, there set in an evolution which during the subsequent 150 years, supplemented by research work of men like Gilbert, Kepler, Galilei and Huygens, led in 1687 to the publication of Newton's *Philosophiae naturalis principia mathematica*. In view of the fact, that the representatives of the newly developing science on nature henceforth also began to apply exact trials and mensurated experiments as had been customary in handicraft and practical techniques, the 18th century in the domain of anorganic natural science was gradually led to complete departure from the teachings of Aristotle and his followers, and from Ptolemy's picture of the universe.

In consideration of all these innovations it is easily understood, why in the 17th century the further existence of antique science has survived to a very limited degree only. Instead, there took place the final stage of an important intellectual dispute, which set in shortly after Aristotle's death and was continued, apart from occasional breaks, until the time of Scheele and Lavoisier.

At first, no enmity towards the heliocentric system of Copernicus was exhibited by the Church. For the time being, the controversy as to its validity or absurdity was left to the astronomers and physicists; Tycho Brahe, reasoning from the point of view of natural science, expressed against Copernicus' teachings practically the same reservations as had been raised by Ptolemy. From the very beginning it was clear to both followers and adversaries of Copernicus, that the theorems on fall and throw proclaimed by Aristotle and the Scholastics could not possibly be brought into compliance with a heliocentric universe. Even so, this was not so essential a difficulty as would not have been overcome by keeping in mind ancient precedents. Cardinal Nikolaus Cusanus, falsely called a predecessor of Copernicus, expressed the opinion based after all on Platonic reasoning, that a fragment torn off from any terrestrial or celestial body would tend to unite again with matter identical, and to constitute a totality, with it. In this way a stone thrown would not so much aim at dropping towards the centre of the world where, according to Aristotle, all heavy matter is supposed to accumulate, but it would rather strive to unite again with its totality, the Earth. In a similar manner, a fragment of the moon, in its free fall, would tend towards the moon, if by some force it had been torn from it.

No physicist who up to the end of the 17th century had ackowledged adherence to Copernicus' system, could help becoming familiar with the doctrine of an Earth rotating round its axis and revolving around the sun; and each of these physicists, whether his name was Galilei, Kepler, Guericke, Huygens, Newton or Leibniz, did it in his own way. It is noteworthy to observe here, how from the multitude of problems on hand each of these scientists selected one of special interest to himself and how he followed, with some sort of stubborn determination, a trend of his own in attempting to solve his respective problem. It would almost seem, as if all particularly prominent men, when aiming at the solution of a task of special interest to them, were held back by a sort of protective attitude which prevented their paying attention to essentially significant notions of others—an attitude obstructing their reasoning from being diverted into lateral channels of thinking. Kepler attempted to discover the shape of the orbit of Mars, and as a result of many years of patient research he came to perceive the fundamental laws of planetary motion. However, he rejected any thought of a multiple number of solar systems, considering the fixed stars to be distributed over a relatively thin spherical shell. Galilei's effort went towards explaining the axial rotation of the Earth as its natural motion, and he established purely kinetic laws for throw and fall; but, at the same time, he refused to acknowledge the validity of Kepler's tenets. Guericke, in turn, a much younger contemporary of Galilei, Kepler and Descartes, would not accept either Kepler's elliptic orbits nor the principle of inertia, promoted by Descartes and by Galilei's pupils; he also repudiated Christoph Scheiner's notion of sunspots as being objects in the sun's outer shell. On his part, Guericke strove at recognizing the essence of interplanetarian and interstellar space, considering it devoid of matter and infinite; for this reason he, as well as his contemporary Athanasius Kircher, subscribed to the tenets of Giordano Bruno, who proclaimed a multiplicity of worlds spread over the boundless widths of space.

It is unknown, at what time Guericke took up the study of the nature of world space. Even while studying at Helmstedt or Leyden, he may have heard of the controversy on the existence or non-existence of a vacuum. But it must have been much later, probably not earlier than 1645, that he considered this problem seriously. After having returned, from studies in France and England, to Magdeburg where he was made member of the local city council in 1626, he probably lacked the time to attend to anything but his administrative duties. Beginning with 1629, both the citizens and the city council of Magdeburg were fully occupied with the hardships of war; later on, following the annulment of the previous urban structure Guericke was made, in 1630, chief of the municipal building department of Magdeburg. This was the beginning of a period in Guericke's life, when for some 15 years he was principally occupied with engineering problems. From 1632 to 1646 he served as "engineer", that is a military functionary in the rank of officer, in Swedish and Saxonian service. After Magdeburg had been captured and destroyed, he continued working as an unsalaried member of the city council. In virtue of this twofold occupation, Guericke soon became the representative and the champion of Magdeburg's interests at the court of the Duke of Saxony; and during his official travels he may have found occasion to entertain more or less scientific colloquies on the structure of the universe. Better still were the opportunities he had while taking part, for close to 18 months, in the peace conference at Münster and Osnabrück. After returning to his hometown—he meanwhile had became widowed—at last he had time to study, theoretically at first, the *pros* and *cons* of Copernicus' tenets and to undertake practical tests in order to investigate problems connected with these teachings. It probably was not earlier than 1650 that Guericke started trying experimenting to create a vacuum. Again it is unknown how long it took from his first attempts of pumping water from a tightly bunged barrel to his discovery of a proper air pump and to his cognizance of air pressure and its effects. But shortly before the end of the Diet of Regensburg, that is before 7/17 May 1654, he managed to demonstrate several experiments of this type to Emperor Ferdinand III and to some dukes and princes. These experiments were described in 1657 by the Würzburg Jesuit Kaspar Schott in his *Mechanica hydraulico—pneumatica*; the same author reports, in 1664, of the continuation and progress of these experiments in his *Technica curiosa*. Upon the insistence of his friends, Guericke himself had completed as early as on 14/24 March 1663 the first report entitled *Experimenta nova (ut vocantur) Magdeburgica de vacuo spatio*. From exactly 7 years later is dated his preface to the reader, while his dedication to Friedrich Wilhelm, Duke of Brandenburg, 1/11 November 1671; the title page reads: Amsterdam, printed by Johann Jansson von Waesberge, 1672.

Outside of Italy, no academies nor scientific societies, not to mention did not start appearing until the last third of the 17th century, or the 17th century. Only at places where many people assembled, such as Diets, County Sessions or Fairs, diversified news were to be had and discussed; and only from Fair Catalogues and the first "New Gazettes" was it possible to learn about political and scientific events. Compendia, especially those prepared by members of religious orders, like Mersenne, Kircher, Riccioli or Schott, took the place of Academy Annals which did not start appearing until the last third of the 17th century, or the first scientific periodicals of the type of *Philosophical Transactions* or the *Acta Eruditorum Lipsiensia*.

Only upon due consideration of these circumstances one gains a fairly authentic picture of the position of a man like Guericke. As city councillor and mayor of a considerably destroyed town, he would have had but little chance of taking part in the scientific life of his time, had he not been sent on diplomatic missions, following the Westphalian Peace Treaty, to Nuremberg, Vienna, Prague and, in 1654, to Rogensburg. In these cities, where peace conferences were held, and at the Imperial Court he met men with whom he was able to discuss scientific problems he was interested in. In this way he came to know, at Regensburg, the Capuchin monk Valeriano Magno who first told him about Torricelli's experiments, and Johann Philipp von Schönborn, Duke of Mainz and Bishop of Würzburg who, while in Regensburg, bought Guericke's apparatus and had it sent to his residence at Würzburg. Here Kaspar Schott, at that time professor of mathematics at Würzburg University, repeated the Magdeburg experiments and exchanged letters on this subject with the inventor, the Magdeburg mayor.

With this correspondence as basis, the evolution of Guericke's experiments with his vacuum pump can be followed practically step by step; at the same time these letters give us insight into the gradual evolution of his scientific knowledge. We note from Guericke's correspondence with Schott and from his own announcements presented in the *Experimenta Nova*, how in the middle of the 17th century a scientist deeply interested in Copernicus' theory contrived to reconcile it with the tenets proclaimed by Aristotle and the Scholastics. And it seems noteworthy, that a great many of the writings upon which Guericke based his assertions, had Jesuit Fathers as authors. It is only as to the essential traits of the heliocentric universe that Guericke cites as references the writings of Galilei, Kepler, Ismaël Boulliau or Philipp Lansberg; and he conforms to their arguments in his effort of refuting the objections raised against Copernicanism.

As far as Aristotle's natural philosophy influenced Guericke's cosmological conceptions, characteristic is the latter's reasoning regarding the structure of the world and the theory on motion connected with it. To him the World seems to be orderly patterned, a "Cosmos," built of a number of homocentric shells. It consists of two layers, essentially different: one called the sublunar, the other the supralunar world. The latter, that is, the world extending outward from the concave part of the moon-zone and comprising the seven planets: Moon, Mercury, Venus, Sun, Mars, Jupiter and Saturn, as well as the shell of fixed stars enveloping all these zones, Guericke considered unalterable. This supralunar world he believed to consist of some celestial matter, a fifth essence *quinta essentia*, fundamentally different from the four elements of the sublunar zone: fire, air, water and earth. The motion characteristic of the celestial spheres is a pure circular motion corresponding to their spherical shape; and, disregarding Kepler's arguments, Copernicus himself as well as Galilei and Guericke are convinced of the strictly circular orbits of the planets. Beyond and outside of the heaven of the fixed stars is placed the invisible clockwork of the celestial universe, the *primum mobile* or prime mover. Below it, yet above the sphere of the fixed stars, there was later introduced what was called the *secundum mobile* or second mover, accounting for the equinox motion. Beyond the *primum mobile*, Christian belief imagined a tenth Heaven, the *coelum empyreum*, supposed to be the abode of the blessed.

In contrast with the everlasting celestial world, the sublunar world represented the sphere of the four elements, a world of arising and passing away. The elements were changeable within themselves; their motion was only rectilinear, either towards the centre of the universe or away from it. The element Earth, being absolutely heavy, moves by its very nature always vertically downwards, the element Fire, being absolutely light, always vertically upwards. Relatively heavy or light were the elements Water and Air, and in compliance with this relative weight their natural place in the Cosmos was above the Earth and below the Fire. The domains of the four elements were layered, starting out from the centre of the world successively as the domain of Earth, of Water, of Air and of Fire respectively, each on top of the other. Order in the Cosmos is perturbed whenever a body, for example one in which the element Air predominates, fails to occupy its rightful place, and therefore such a body is bound to move, vertically downward from the sphere of Fire, or vertically upward from the sphere of Earth. Each of these motions would then be a "natural" one. However, a stone thrown upwards would carry out an "unnatural", an enforced motion.

Guericke made up his mind to deal with these notions, known to him both from the time of his studies and from literature. He was willing to concede some of these beliefs, some others he refused to admit; other beliefs he disavowed on the basis of his air-pump experiments. To the latter decision must be assigned the notion that above the sphere of Air a sphere of Fire is supposed to exist, or the claim made by Aristotle that within the Cosmos there can not exist any continuous void space, no *vacuum coacervatum*, this being the term later used by reference to Hero's *Pneumatics*. It should be remembered, that Aristotle himself had argued against the existence of a vacuum, from the viewpoint of his doctrine on motion. At a later period, there was seen in what was called *horror vacui* the abhorrence of creating any void space, and the tendency of nature towards maintaining a continuity within the bodily world, because it seemed that only in this manner a mutual action of the individual bodies could be safeguarded. This was a conception which, although in different form (as the hypothesis of light "ether"), retained its validity as far as the 20th century.

The way how Guericke considered all these problems cannot be shown better and more explicitly than by the manner how he reports it himself. To be sure, in Volume 2 of *Neue Magdeburger Versuche*, the title of Chapter 3 is *De vacuo* meaning "On the void"; but the title of Volume 2 reads: *De spatio vacuo*, that is "On void space." Thus, conformably we read on the title page of the whole book: *Ottonis de Guericke Experimenta nova, ut vocantur, Magdeburgica de Vacuo Spatio... written first by His Reverence the Jesuit Father Kaspar Schott, professor of mathematical sciences at Würzburg University and now edited, after being supplemented by the inventor himself with diverse more accurate further experiments.* Here Guericke added some discussions on air pressure, the forces acting in the world, the planetary system, as well as on the fixed stars and the vast expanse extending both within and without the sphere of the fixed stars. And the confirmation that it was particularly the essence of universe space that made him reflect upon and experiment, we find both in his "Preface to the Reader" and, in Volume 2, at the end of Chapter 1 bearing the title: "On the Reason why the Author undertook his Experiments on the Void", where he tells us: "Reflecting for a long time upon Copernicus' system and regarding the structure of the world (*circa Mundi fabricam*), I was appalled by the tremendous sizes of all these world bodies and their monstrous distances exceeding man's imagination. But most astounding seemed to me the enormous remoteness (*vastum illud intermedium*) and the infinitely spread space, and always I felt the urge to explore these phenomena. I wondered about this all-embracing something that grants man the abode of his existence. Could it be some kind of fiery celestial matter, massive as claimed by the Aristotelians, or liquid as believed by Copernicus and Tycho Brahe, or is it, perhaps, some most refined quintessence or, even that void space, bare of any kind of matter, that is ever so often being disputed?"

This plainly indicates the foremost problem ruling all of Guericke's reflexions and investigations. The subject-matter of the first volume of his book, entitled: "On the World and its Structure according to the most popular Opinions of Scientists", gives us a picture of his keen intellect based on Copernicus' teachings, and combating the contemporaneous theorems of both Scholasticists and Cartesians; the second Volume: "On Void space" is written in greater detail.

The first Volume of *Experimenta nova Magdeburgica* briefly discusses the three best-known world systems: Ptolemy's, Copernicus' and Tycho's; a fourth added is, an "improved" system, that of Guericke. Of particular interest are, in this first volume, Guericke's reflexions given in Chapter 35, entitled: "On Space, merely imagined, outside the World". Here, apart from other topics, Guericke discusses the arguments raised by the professors of Coimbra University; he also debates commentaries to Aristotle's physics, where the discussion dwells on "the space extending both inside and outside of Heaven". The Coimbra professors believed *spatium imaginarium* to be unreal and a purely intellectual fabric, while other scientists rejected this opinion. Guericke also speaks of Descartes, and calls attention to his own comprehensive dealing with this subject-matter in his Volume 2.

This Volume 2 "On void space" constitutes some sort of compendium of all teachings on space and time discussed in the 17th century, on the vacuum, on being and not being, on the notion of boundlessness, immeasurability and eternity, and on biggestness and smallestness. It is understandable that he dwells most explicitly on the problem of space, and distinguishes between Aristotle's notion of place or position and the notion of space. He interprets the Aristotelian-Scholastic notion of space (*locus*) as defining "something that encompasses, or some sort of vessel of another body contained within", or: "space is the outer surface of a containing body adjacent to the contained (*extremum continentis cohaerens contento*)"; or: "space is the ultimate confine of the containing body (*ultimus terminus continentis*)". In contrast to Aristotle's concept, Guericke is of the opinion, that space represents a reality that is imaginable, though not directly perceivable by vision. To him, space constitutes the general container of all matter; experiments show that it can either be void or filled. Being a believing Christian, the Magdeburg mayor then dwells on Heaven, discussing the question whether space should be considered something created or not created, what is going to be the role of space on Judgment Day, and what is meant by "Heaven the Abode of the Blessed"". The last Chapter of Volume 2 deals with "The Biggest and the Smallest", ending most characteristically with the following pronouncement: "Indeed, no created thing is so enormously large that space is not infinitely greater; on the other hand, nothing is so small—in force or spirit—that space is not infinitely smaller and more subtle yet. Hence, as is easily seen, it is not against nature that the dust left from our bodies, as fine as it may be and wherever it may rest in the earth, still remains in space, and that in space or by space it can easily be put together again and consolidated. Consequently, also, our bodies can easily be recalled to life and resurrected on Judgment Day, in order to render an account of the deeds committed during our present life."

It is readily understood why a man who, unaware of Torricelli and Viviani, came to comprehend the essence of air and air pressure, repudiated Aristotle's doctrine about the four elements. As mentioned before, Guericke denied the existence of a sphere of fire above the zone of air, and treated very sceptically the assumption of a substance comparable with the element Fire. Moreover, he had barely any reason to debate the doctrine of the elements, because he really was little interested in chemical or physiological-chemical problems, but solely in cosmological questions. However, because, like his contemporaries

Kepler and Descartes, he had abandoned Aristotle's physics, he was bound to attempt, by other means, an explanation of the forces acting within the *Machina mundi.*

For Copernicus there had been no need for all of this, because from his purely astronomical point of view he was interested in the circular orbits of the celestial bodies and attempted to develop a phoronomy of planetary motion, not at all a celestial mechanics nor, even less, a celestial physics. Different was the case with Kepler; this scientist was tempted to evolve a system of telluric-cosmic magnetism controlling planetary motion, induced by Gilbert's book: *De Magnete, magneticisque corporibus at de magno Magnete Tellure Physiologia nova* which appeared in 1600. Descartes, being a philosopher and a mathematician, wanted much more and actually reached his goal: he was the first who completely replaced the Aristotelian-Scholastic *philosophia naturalis* by fully new *principia philosophiae*, a mechanistic image of nature's full activity—a theory which, at least on the European continent, had its followers until about the middle of the 18th century.

Guericke who, much like Kepler, only aimed at establishing a system of cosmic physics, conceived a celestial physics of his own and discussed its essence in volume 4 of his *New Magdeburg Experiments,* where he dwells on the forces acting in the universe and on other subjects depending on them (*De virtutibus mundanis at aliis rebus inde dependentibus*). In Guericke's speculations, "these forces are neither substances nor accidentals, but rather effluvia of universal bodies, cognate to them and from which they issue. However, a difference must be made between such effluvia which originally were part of the bodies from which they originate, and such that flow into these bodies and are absorbed by them.... They are called "forces acting in the universe" because they act principally on bodies of the universe, that is, the planets, but likewise on the earth and the sun, and on parts of the earth as well. Some of them are of bodily, some of non--bodily character ... To give an example, air is a bodily force of the earth, that is, the bodily effluence of all earthly things."

To Guericke non-bodily forces emanating from the earth are: "1. the driving force (*virtus impulsiva*), 2. the force of assimilation and discharge (*virtus conservativa et impulsiva*), 3. the force of magnetic direction, 4. the force of torque, 5. the force of sounding, 6. the force of heating, *etc.* To the non-bodily forces reaching us from the sun, belong manifestly the forces producing light and colour, *etc.* Quite a few arguments imply, that a force carrying frost is emanated from the moon."

Guericke hoped to prove the existence of a number of these forces acting in the universe, by means of a model of the globe, a sulphur ball. This model, when given a thrust, reveals a *virtus impulsiva* by continuing its motion for a while; rubbed with a dry hand it attracts light bodies and also repulses them; it can be rotated and issues a crackling noise when held near the ear. When rubbed by hand, the ball shines in the dark much like sugar when broken up; upon more intense rubbing it gets warm without, however, any directional force. This latter force can only be created by melting a magnet into the ball.

The air pressure experiments show, that upwards the air grows continuously thinner, and that ultimately it changes into nothing. The same rule applies to any force of bodily or non-bodily action. Each force of this kind is limited in its sphere of action, its *orbis virtutis,* is of definite range; nor would motion ever last infinitely. By the way, how typically Scholastic is this mode of thinking! Guericke, like Kepler, is convinced that every body in the universe has a soul, *anima,* of its own. In this he clings to one of Aristotle's notions or, rather, he transfers it suitably upon the celestial bodies of Copernicus' system which, including the sun, rotate around their axes without any impulse from without. Guericke believes the Earth to have a planetary soul lacking, however, the intellect possessed by the human soul. To this Earth he ascribes the faculty—the same as possessed by the animal body—of absorbing and retaining anything serviceable, and discharging the unserviceable. This he deems to be the reason, why the *vis conservativa* of bodies of the universe can not be likened to something like the force of attraction of electric charges or forces of Newton's type, and why the *vis expulsiva* must be looked upon as a force of discharge, not a force of repulsion.

It would be futile to discuss here at length all these problems, interesting as they may be. All that has been said above should suffice to indicate, how Otto von Guericke's world outlook was affected by a medley of Aristotelian, late Scholastic and Baroque traits.