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london and paris: two sciences of the earth

LONDON AND PARIS: TWO SCIENCES OF THE EARTH

By the third decade of the 18th century, the polemic over the shape of the Earth had acquired a high social visibility in keeping with the furious contradictions under dispute. In fact, after Mairan's memoir was published, Newton and Descartes' followers and supporters were in a state of confrontation within the general framework of the serious clash between theoretical predictions and experimental results. To make matters worse, new dimensions of the debate would very soon increase in importance.

Salient among these were the theological implications of the Newtonian propositions. The physics and natural philosophy of the 18th century were based on the corpuscular, mechanistic heritage of the 17th century. The Newtonian concepts of atomism and the vacuum were loaded with Epicurean and atheistic connotations which were hardly acceptable to a scientific community whose slow process of laicization had still not been able to counteract the enormous influence of the Church. After the Christianization of Cartesianism wrought by the occasionalist Mallebranche, the philosophers indebted to Descartes abandoned the deist standard, according to which the divine being was no more than a metaphysical piece within their conception of the cosmos. God, who had created a world in motion subjected to inert laws that prevented its degradation, was obliged to respect the principle of the conservation of motion: Immutability limited all His possible acts at the very moment of creation, leaving Him, afterwards, trapped by the rules He Himself had established.

In Newton's physics, where ethereal matter, the support for every interaction and a guarantee of the conservation of the *quantity of movement*, was expendable, it was nevertheless necessary to reinforce the image of an omnipresent God whose continuous intervention providentially verified the laws of nature. The Newtonian ether, understood as divine *sensorium*, revealed through its presence the Creator's will to assure the cosmic order at every moment. This type of Anglo-Saxon pantheism would constitute a powerful obstacle to the spreading of Newton's work on the continent. There were many who put up fierce resistance, but none so powerful and influential as the Society of Jesus, which through its teaching and vigilance maintained a broad network of schools and an accredited vehicle for the expression and diffusion of its ideas in the Memoires des Trevoux.[1]

Much broader social repercussions were produced by identifying ideas with their countries of origin, a tendency for which the institutions that arose during the previous century were already prepared. There were several circumstances that contributed to the slide down the smooth spiral of patriotism. In the proliferation of theoretical alternatives that existed after the breakdown of scholasticism, development was possible only for those traditions that were backed by solid institutional support. The birth of new academies through royal public sanction presumed not only legitimacy of a political character, but also the Crown's acceptance of a commitment to certain groups, ideas or programs of scientific activity. The expression of their results in vernacular languages and their rapid entry into technological development projects in the naval and military sectors --central columns in the structure of modern states-- helped the process along. Of course, men of science also felt comfortable in the new situation: their role as servants of the Crown and their contribution to the project to rationalize the social and productive structures was highly beneficial to them. In exchange for their increase in security and social standing, the King exacted payment by silencing dangerous regenerative concerns and domesticating their learning. They were transformed from wise men into academics; their learning, hitherto ornamental and courtly, was called on to occupy a privileged position among the other instruments of ideological combat (theater, literature and so on) in the struggle against superstition and untruth. The new rationalism based on geometry and experiments, as their publicists insistently declared, always held the promise of truth. Everyone knew it and no one refused --for the moment-- to participate in such an exciting game. It was, in sum, inevitable that nationalist prejudices would take root in scientific groups. Newton, on his pedestal of glory, was a symbol that could reflect the superiority of a race or nation. Between his Principia and the ideal of the new England lay a long road whose length was covered with extraordinary speed.

Theory versus experiment, Newtonianism versus Cartesianism, laical versus scholastic theological doctrine, *savant* versus academic, England versus France--all these were, in the end, powerful alternatives destined to activate a polemic and kindle fiery passions.

The Young Geometricians

Not all the members of the Academy of Science considered the geodesic results published by J. Cassini to be as accurate as Fontenelle did, nor did they all accept Descartes' vortices. Within the institution there was a small group of "young geometricians" who harbored no doubts about the superior explanatory and predictive power of the Newtonian principle of universal gravity: "It is, in fact, the young geometricians, both in France and in foreign countries, who have decided the fate of the two philosophies. [2]

The foreign members of the group to which D'Alembert refers were figures who, like Euler, D. Bernouilli, Boscovich and Celsius, would two decades later play a fundamental role in the development of 17th century physics. In France, however, the scientists were more combative and acquired a certain reputation as a heterodox group. The most active members were Clairaut, Maupertuis and La Condamine, who together with Voltaire, Algarotti and Koenig belonged to the circle which, gathered around Mme. Chatelet and acting from Cirey, systematically harassed the Parisian Academy. Few in number, they also had very little influence. Time, however, would be their best ally; Cartesianism was preparing for its last and most violent battle. But this gradual process of ideologising the debate over the shape of the Earth took place in distinct scenarios that deserve to be recalled.

Paradoxically, the first eulogy for Newton after his decease came from the Paris Academy of Sciences. As was traditional after the death of one of the Academy's members, Fontenelle himself, in his post of Permanent Secretary, now had to fulfill his obligation and honor the memory of the great opponent of Descartes' work. The solemn moment for the speech was anxiously awaited by Newtonians and Cartesians alike. Everyone's expectations, however, were to be disappointed to some extent, since both Newton and Descartes were elevated to science's highest pedestal, equaled in wisdom and categorized as creators of the two greatest philosophical systems ever known to humanity.[3] From a tactical point of view, this was the position that would be most favorable to Descartes' partisans, upholding the Academy's good name and the work of one of its most distinguished foreign members. In England, on the other hand, this comparison seemed virtually an insult. Recalling the atmosphere he observed during his visit to London, Voltaire wrote, "Here they have eagerly translated into English and read the eulogy given by M. de Fontenelle for Mr. Newton at the Academy of Sciences. In England they expected M. Fontenelle's verdict to be a solemn declaration of the superiority of English philosophy; but when they saw that he was comparing Descartes to Newton, the whole Royal Society of London rebelled. Far from coming to their senses, they have criticized his speech. Some people (and not the most philosophical of them) even felt hurt by this comparison merely because Descartes was French." [4]

In addition to comparing them, Fontenelle also had to reflect the sentiments that the majority of Academicians had been expressing on the thorny issue of gravity. His words were eloquent enough: "It is not known what Gravity consists of. Sir Isaac himself did not know.... He uses this word from the beginning to identify the active force of bodies, a force, however, unknown, and which he does not propose to explain; but if it can act equally by Impulse, why not give preference to this clearer term? Because we must agree that there is no possible way to use both indiscriminately as they contradict each other in good measure. The continuous use of the word Attraction, supported by most authorities and also perhaps by the inclination that Sir Isaac, it is believed, had in the matter, familiarizes the reader with a notion disdained by Cartesians and whose condemnation has been ratified by all other philosophers. We must be careful: we wouldn't want to imagine that there was something real in it, and thus expose ourselves to the danger of believing that we understand it!" [5]

What is certain is that Fontenelle, like other scientists and philosophers, never understood the concept of attraction. Beyond the matter of the two great conflicting cosmic visions, however, we must examine the purely lexical question here: "If M. Newton," wrote Voltaire in 1734, "had not used the word "attraction" in his admirable philosophy, our entire academy would have seen the light, but he had the misfortune to use a word in London which in Paris has been associated with a ridiculous idea, and only for this reason have they passed judgment with a degree of recklessness that will one day bring little honor to his enemies."[6]

The harsh analysis with which Voltaire threatened the opponents of attraction was not going to last long. For D'Alembert, Fontenelle's curious reflection and the metaphysical nature of the discussion were obvious proof of the need to construct a new order of discourse, rigorously subject to the code of no appeal--mathematical reasoning. "The history of our disputes," d'Alembert said in 1759, "exhibits an abuse of words and vague notions, the progress of science held back by words, emotion disguised as zeal, stubbornness in the name of firmness: this shows us how inappropriate arguments are for letting in the light."[7]

For A. Maury, historian of the Paris Academy of Sciences, there was no doubt about the explanation for all this: "National prejudice, like religious prejudice, as you can see, exerted a troublesome influence on the group."[8]

In the context of the tense relations existing between the two national scientific communities, the new and varied implications of Mairan's memoir met with a fulminating response in England. The Newtonian "guard" of the

Royal Society --Keill, Pemberton, Folkes, Maclaurin, Taylor-- would not tolerate an attack on the most spectacular feature of Newton's physics. In their name, Desaguliers came out in defense of the principle of universal attraction with three memoirs published in Philosophical Transactions in 1725.[9] The first of these attacks the procedure used and the conclusions obtained by J. Cassini. His reasoning is simple. How could the small difference between the degrees to the north and south of Paris be a sufficient argument to warrant a conclusion about the shape of the Earth if they had been measured with instruments whose degree of precision could not guarantee errors of less than 200 fathoms? He cites a long list of deficiencies in the overall practice of the procedures as proof for discrediting the work done in France. In the second memoir he contrasts the geodesic and experimental method with Newton's geometric method. Recognizing the existence of several gaps in his countryman's treatment of the problem, he uses the same arguments as in the previous memoir to reject the supposed objectivity of the empirical data obtained by the Cassinis. The third essay completes the scrutiny of French science, labelling Mairan's memoir as unreasoned, unscientific and thoroughly unsubstantiated by experiment.

The polemical, obscure and overly succinct style of these three writings did not weaken their impact on the Paris academicians. Some of them --the "young geometricians"-- found arguments in them good enough to strongly recommend a revision of the geodesic procedures and the shelving of the thesis of the oblong earth. The event that would propel them to the front lines of the battle was imminent. The isolation in which their thoughts developed --even their own memoirs had to be published in Philosophical Transactions in English or Latin-- was their main weakness. Under such circumstances their presence was no more than a nuisance which the Academy did not yet perceive as dangerous. In 1732 things began to happen. J. F. Lalande, when he comes to this year in his Bibliothèque Astronomique, begins the review of work published as follows: "This year, which was the year of my birth, was a remarkable year for astronomy. Maupertuis began to establish Newtonism in France...and three years after the measurements undertaken to ascertain the shape of the Earth he provoked a revolution in astronomy."[10]

In fact, the publication of astronomical works during the first half of the 18th century underwent a notable increase, a fact testified to both in Lalande's work and in Weidleri's Historia Astronomicae (1741). The graphs presented earlier in this book also show that the proliferation of literature on the shape of the Earth coincides with the onset of the third decade of the 1700's. On the topic at hand, 1732 is an especially significant date. With the publication of the Discours sur les differents figures des astres (Paris, 1732), Maupertuis made the first exposition and public defense of Newtonism in France. At the same time, as we have seen, he sent a memoir to Philosophical Transactions in which he addresses the subject of the shape of the Earth from a Newtonian perspective. The mathematical part of the Discours presents nothing new with respect to this latter work. Here we are interested in analyzing the other aspects of its contents. After comparing the "systems" of Newton and Descartes according to the model instituted several years earlier by his countryman Fontenelle in his Eloge a M. Newton, he reaches totally different conclusions. Less essentialist than the Permanent Secretary of the Academy, he states that Newton's greatest advantage over Descartes is that the former used the word attraction to designate --without other connotations-- a physically verifiable phenomenon. To Maupertius it made no sense to ponder the cause that makes objects fall. And in any case the answer to this type of question did not belong to physics or geometry: "Everything we have just said proves that there is attraction in Nature; and I do not propose to demonstrate it either... Attraction, to put it one way, is nothing but a matter of fact."[11]

As a "geometrician," the recognition of this phenomenon did not commit him to any general philosophy of the Universe, but just in case his words might be the object of tendencious interpretations, he added, "To assume this force and its law is not to make a system; it is to discover the principle by which observed facts are necessary consequences."[12]

In that same year another memoir by Maupertuis, published in the official journal of the Paris Academy of Sciences, put a definitive seal in the eyes of all Europe on his commitment to Newton's work.[13] Although in June 1734 Voltaire lamented that not even two hundred copies had yet been sold, echoes of the Discours reached the most distinguished circles on the continent: "M. Mushenbroek said, speaking of this little book, that it was in fact the best work in Physics ever produced in France," Voltaire told Maupertuis in November 1732.[14]

Once again Fontenelle found himself obliged to come forth in defense of Cartesian orthodoxy, again publicly displaying his philosophical repugnance for a principle which, in his mind, would restore occult causes to Physics. "Attraction, properly speaking," Fontenelle said, "is nothing more than a name which is given to an unknown Cause, whose effects are perceived everywhere.... M. Newton's excellent work, which is a pillar in its field, was written in such a fine, intelligent manner, so far above the common run of Geometricians, that it has needed Commentators, and the most able Geometricians, not only English but also French, have not disdained to be such."[15]

Fontenelle was mistaken when, in his conciliatory stance, he suggested that the interest in the Principia exhibited by Maupertuis and other "geometricians" in the Academy was exclusively mathematical and the result of a desire to apply "sublime mathematics" to specific physical problems. Still another memoir by Maupertuis, read in the Academy in 1733, again insisted on his earlier point of view. "I hereby abandon everything that can be determined a priori about the shape of the Earth. I limit myself to considering only facts..."[16]

And what were these facts? The substantiation that, independent of the greater predictive power of the principle of universal attraction, astronomers had verified that all planets subject to a movement of rotation on their axis were flattened at the poles. Maupertuis was right, but the observations alluded to could not be very precise with the instruments of his time, an argument which, not without reason, was conveniently brandished. But in addition things were not so simple; each party to the debate obtained the empirical proofs he needed to support his own position. We hear Celsius complaining about this in a letter to Delisle: "I have a great desire to know if you, sir, have examined the observation of M. Godin, who wants the vertical diameter of the Moon to be greater than its horizontal diameter. M. Manfredi has confirmed this observation. M. Cassini has repeated the same observation in the observatory, however he, like M. Godin, has measured the horizontal diameter by time and the vertical with micrometer readings."[17]

In other words, a very unconvincing and sloppy piece of work. But beyond that, and without the need to create a new empirical base, the same facts, as Fontenelle explains, permit a different interpretation. Referring to Cassini's figures, he said, "It is evident that the present measurements must be preferred to those resulting from geometric theories based on a tiny number of very simple suppositions [an implicit reference to the principles of the channels or the plumb line, proposed respectively by Newton and Huygens] from which all the complications of physics and the real world have been voluntarily omitted. If Jupiter is a flattened spheroid, this would be more exactly deduced from the circumstances required by the theory, but this would not make the Earth the same."[18]

This text introduces something new which ought to be emphasized. The retreat to Cartesian orthodoxy led the Academy's Secretary to a denial of another of the basic pillars on which Newton's physics was constructed: the necessity to respect the principle of the analogy of Nature, which is consistently the same throughout the Universe, and the possibility of being able to draw conclusions from the observed about the unobservable. The experimentalist root of the argument developed by Fontenelle seems surprising, and the different attitudes in which the dynamics of dialectical confrontation surrounds the partisans of one choice or another are curious: while the Newtonians claim the primacy of their theoretical fundamentals, the Cartesians cling to the indisputable value of observations made by astronomers. In sum, the situation was very complex, and the problem did not lie with the experimental results and their interpretation. In a nutshell, each party already had the explanation for what would happen. Dialogue was impossible. For Fontenelle, as for Maupertuis, there was no room for doubt: "It is true that if one wants to understand what they say, there are only impulses, and if one is not concerned about understanding it, there are attractions and anything you want; but then Nature is so incomprehensible to us that perhaps it would be wiser to leave it as it is."[19]

The epithet "young geometricians," as we suspected, established a line of demarcation in the Academy membership between two different ways of approaching the study of nature, which corresponded to the divergent attitudes in respect to Newton's theses. It was, in other words, the wall behind which a presumably threatened logic was safeguarded.

Brunet's study on the introduction of Newton's theories in France, cited earlier, explained why even at the end of the 17th century there was only a very small number of French scientists who declared themselves followers of Descartes. Even during the first two decades of the 18th century, it could not be said that Cartesianism was the official philosophy of the Academy, in spite of the efforts of its greatest divulgers, with Fontenelle himself at their head. On the contrary, there was a bias against the mechanistic materialism condemned by the Roman Catholic Church. D'Alembert has also described this phenomenon --with great insight, in our opinion-- as well as the impact caused by Maupertuis' works: "Not only were they (Newton's theories) unknown in France, but scholastic philosophy still dominated after Newton had overthrown Cartesian physics; and the vortices were destroyed before we thought of adopting them. We were as slow to accept them as we were to reject them. One only has to open the books to see with surprise that it is not yet thirty years since France began to renounce Cartesianism. The first among us who dared to openly declare himself Newtonian is the author of the Discours sur la figure des astres... M. de Maupertuis thought that one could be a good citizen without blindly espousing the physics of his country, and in order to attack that physics, he needed to have courage, and we must thank him."[20]

Soon we will see in detail just how much courage and bravery he needed in order to maintain certain scientific ideas that finally obliged him to leave Paris, accepting the Presidency of the Berlin Academy, a position offered to him by Frederick II of Prussia himself.

The Academy Divided

The first important setback that seriously affected Maupertuis came from his own teacher in Basel. Perhaps the polemic would have unfolded in a different way if the distinguished mathematician J. Bernoulli had not adopted such a favorable position on the subject of Descartes' vortices. In fact, the Essai d'une nouvelle physique celeste (1734), in touching on the theme of the shape of the Earth, concluded with the following sentence: "After this fortunate harmony of our theory with the celestial observations, can one any longer reject the shape of an oblong spheroid for the Earth, which is in addition based on the measurement of degrees of the meridian undertaken and executed by Cassini himself, with unbelievable accuracy?"[21]

Jean Bernoulli's memoir was included in the third volume of the Pièces qui ont reporté le prix de l'Academie royale des Sciences (1734), along with another by his son Daniel ("Disquisitions physico-astronomicae") in which, according to Brunet's account, one can detect the influence of Newton on the father and the veiled acceptance of his theses by the son.[22] The volume included an "Advertissement de l'Academie" in which the institution announced its independence from the two systems in dispute. This declaration, however, was not swallowable. Of all the commentaries on Jean Bernoulli's memoir, we take for our own the words with which Montucla --in an opinion shared by I. Todhunter-- described the significance of the event: "However, this whole edifice was totally demolished, once the flattening of the Earth was demonstrated; there is no better proof than this work of how many arguments similar to Bernoulli's could be made, even though some may seem consistent with mechanics."[23]

J. Bernoulli's memoir perfectly reflected the opinion of the majority of the Academy members. Although we have expressed our suspicions about the impartiality of this decision, one could allege enough motives to justify it, and among them the most important would be the renowned prestige of Bernoulli's name. Many facts, however, confirm that a large part of the French scientific community was quite receptive to works favorable to the thesis of the oblong Earth, heedless to the serious imperfections found in many of them. One example will suffice to confirm this opinion.

In 1735, D'Anville, a royal geographer and therefore a man of recognized prestige and influence, decided to take an active part in the polemic. Using findings from different geographical latitudes and longitudes on all the continents, and following seven different mutually compatible criteria, he concluded that the Earth was oblong. The commentators of Trevoux, satisfied with these conclusions, wrote in the same year, "Finally, Physics joins Geography in favor of this flattening, since it is easier to think that the elliptical figure is more suitable than the spherical to control and maintain the daily movement of the Earth about its axis."[24]

D'Anville, with such questionable sources, had had no misgivings about affirming that all the cartography of the epoch had to be revised since, according to his calculations, the Earth was a spheroid emphatically flattened at the equator, whose ratio between the axes was 16/15. This was an preposterous exaggeration: the Earth had no longer ceased to be a watermelon in order to become a melon; rather, the planet now resembled a cucumber. In spite of the rejoinders published by French cartographers, more technological and beyond "philosophical disputes," D'Anville insisted on his point of view a year later.[25] Bellin, an engineer in the Dépôt des Cartes et Plans de la Marine, scandalized by his countryman's audacity, reflected on how D'Anville's new armchair geography had come to be a lower kind of knowledge compared to the significance of astronomy and geodesics: "...so here we have enlightened Geography in such a manner that one can no longer err about the shape of the Earth, nor about its size in general."[26]

However, one should not confuse the work done by French geographers during the first half of the 18th century with what we are here calling mathematical geography or, if you prefer, geodesics. The armchair work done by Delisle or the first D'Anville, reformers of cartography in France, consisted of critically extracting the geographical data necessary to *situate* or *locate* a geographical point from charts, chronicles --often imaginary-- of voyages, logbooks, and information supplied by their correspondents. This type of geography, subsequently ripened by naturalists and educated travellers, did not enjoy the prestige of the other kind, based on astronomy and evolved in a different, sometimes contrary, direction. Only at the end of the century would they come together again in the copious works of Baron Humboldt.

At the beginning of 1733, the Marquis of Poleni published an article in the Journal historique de la Republique des Lettres that would give a new twist to the situation created in the heart of the Academy.[27] Given that the geodesic operations carried out until that time in France were inadequate, Poleni argued, it would be wise to verify whether their conclusions were correct; supposing Newton's hypothesis to be valid, the value of the average degree of the parallel that passes through Paris ought to be 38,546 fathoms, while according to Cassini's thesis it would have to measure 37,769 fathoms. The difference of 777 fathoms was enough to make it worthwhile to carry out the necessary procedures to settle the matter once and for all. The way Poleni presented his arguments, the proposition seemed totally reasonable. The thirty-one fathoms of difference found by Cassini and the harassment of Maupertuis and his followers suggested that new observations were in order. In June 1733 J. Cassini was engaged to continue mapping France, giving priority to the St. Malo-Strasbourg parallel. In that same year he reached the Atlantic coast, and in the following year his observations were finished in Strasbourg. The arc measured, using Picard's observations in the extreme west and Eisenschmid's at the other vertex, was 5°33'. The result, once again, confirmed his earlier conclusions: they found 680 fathoms difference from what ought to have been obtained by assuming a spherical shape. Incomprehensibly, they did not verify the old measurements of longitude used, which could introduce in the amplitude of the arc an error of almost 30^s in the time, equivalent to 7'30" of arc. On an average degree of 37,000 fathoms and a total amplitude of 5°30", the possible error was 841 fathoms; that is, once more the uncertainty that affected the results was greater than the actual difference found.

Poleni's critique of De la Grandeur et Figure de la Terre prompted an immediate reply. Cassini, instead of expressing his disdain or rejection of comments made by a man of much less intellectual stature --his habitual response on other occasions-- took advantage of the occasion to describe in great detail all the steps and precautions he had used in earlier works and expected to use in the operations of 1733-34.[28] Both this reply and the very results obtained in the last geodesic campaign heightened the anxiety in the Academy. As with the operations finished in 1718, there were too many uncertainties concerning the quality and efficiency of the method used. All this provoked unprecedented interest on the part of the French scientific community to determine the circumstances, and the methods and instruments that ought to be used so that the results derived from geodesic observations would be accomplished with necessary rigor. A glance at the Memoires de l'Academie... reveals the existence of a spectacular growth in literature on the topic. This work constitutes the principal body of that "révolution dans l'astronomie" of which Lalande speaks, and the point of departure for the proposal to undertake the great geodesic expeditions we will consider below. In sum, it was a great effort aimed at identifying the problems involved in this long debate and, of course, in the search for possible theoretical and experimental solutions. Before bringing this topic to a conclusion, we will briefly describe the main lines around which the Academy's interests centered.

The initiation of operations with a goal measuring a parallel degree of latitude stimulated the publication of a series of memoirs on the most appropriate procedures.[29] L. Godin addressed the problem of how to plot a parallel,[30] proposing a method that consisted of locating by trial and error equidistant points with the same latitude. It was sufficient to confirm that the altitude of a star at the zenith was the same at all of them. The problem would arise when it was not a matter of following a previously plotted trace, but rather in beginning to plot it: finding these points required an enormous number of astronomical readings. In practice the difficulty was so serious that it caused the proposed scheme to be reconsidered a year later,[31] and the publication of a memoir by La Condamine describing a new instrument useful for plotting lines perpendicular to a given meridian.[32]

Godin's two memoirs explained how, by comparing the value of a degree of parallel with the value that would presumably result using the assumption of a spherical Earth, the polemic could be solved in purely qualitative terms: on an oblong spheroid, contrary to what would occur if the poles were flattened, this degree would be larger than on the sphere. It was a method which, applied to the results obtained by the Cassinis on the Paris parallel, supported their previous conclusions. However, matters were not so clear to Clairaut. In 1733 he presented a memoir at the Academy in which he performed a detailed analysis of the geometric methods that would permit prudent conclusions to be drawn.[33] In the same year Maupertuis, using an identical approach, tried to resolve the geometry of the problem by looking for a mathematical expression that would link the observable magnitudes with the ratio known between the axes of the planet.[34] Both memoirs uncovered methods that would permit the analysis of errors and supply new elements of judgment on the question of how and where to make the measurements necessary to measure the magnitude of the planet. For the moment the geodesic problem was partially resolved. The greatest difficulty continued to be the astronomical observations and, especially, two points in particular: astronomical refraction and specifying the moment when a star passes through the meridian.

A memoir by Cassini proposing a method to verify which side of the polemic was the right one[35] was followed by two excellent works by Cassini de Thury and Clairaut, which provided the clearest and most systematic exposition of what we might call the "geodesic experiment."[36] The theme of refraction and the moment of "transit" were addressed by Maupertuis,[37] Maraldi[38] and Mairan[39] in other memoirs which perfected the methods of circummeridional and corresponding altitudes: they justified the need to use long-radius instruments, stars whose altitude at the zenith is low, simultaneous observation in several places, and so on. All the memoirs provided practical rules to verify the divisions of the limb, guarantee the correct installation of the zenithal center and achieve parallelism between the planes of the lens, instrument and meridian.

Delving into the purely geometric considerations of the problem of the shape of the Earth, Maupertuis published an important memoir in which he further developed the considerations he presented in 1733, demonstrating that, given two degrees of meridian, their corresponding latitudes and the equatorial and polar diameters, an algebraic relationship exists among these magnitudes. If E and F are two degrees of meridian corresponding to the mean latitudes S and s respectively, and m is the polar semiaxis, the famous formula was:

$$1-m^2=\frac{2}{3}\times\frac{E-F}{E\times\sin^2 s-F\times\sin^2 s}$$

In view of the different expressions found, Maupertuis advanced in an even more fertile direction: what type of operations would have to be carried out in order to make the differences between the degrees, combined with the inevitable errors, as conclusive as possible? He analyzed the two methods hitherto employed to determine the shape of the Earth (to compare two degrees of latitude or one of latitude with another of longitude that were contiguous) and he demonstrated the presence of excessive uncertainty in the results. The conclusions he reached counseled the measurement of arcs of meridian at sufficiently distant latitudes. "After having given a great deal of thought to this matter, I think the surest method to measure the shape of the Earth must be to adopt the second type, the one in which there are several quantities --different degrees to compare--, and this is what had convinced me to measure a degree near the polar circle."[40]

From the same perspective, Clairaut and Bouguer presented several considerations that modified and improved the set of propositions presented by Maupertuis. Clairaut addressed the problem of whether the shape of the Earth was regular on all its maximum circles, concluding that it was convenient to have at least three degrees of meridian. He also supplied a mathematical expression that permitted errors to be analyzed.[41] Bouguer, using another formula analogous to Maupertuis' formula, showed that in the current state of astronomy it was impossible to find accurate results for parallel arcs.[42] Later we will see how much influence all these considerations would have on the initial development of our academics' work in America.

This quick review of the work carried out in the Academy between 1733 and 1736 to design a precise method for measuring the shape of the Earth ends with the studies on the hourly pendulum. Mairan's study was especially noteworthy, as it became a model followed in all later observations.[43] So was Clairaut's work, which addressed the problem of the isochronism of the oscillations.[44] The flurry of activity of the Academy during the years under consideration here is evident. The conclusion of the operations carried out by Cassini between Strasbourg and St. Malo could not satisfy either the exigencies of accuracy or the new methodological expectations generated by this ample set of memoirs. On March 23, 1734, one of the most committed defenders of the thesis of the oblong Earth ended by reading a memoir in which he recommended making observations of the parallax of the Moon, which might cast new light on the problem. "Since the shape of the Earth," wrote Manfredi, "has been determined by the Astronomers of the Royal Academy of Sciences with direct measurements, carried out with the greatest care and refinements possible, it appears that there can be absolutely no doubt about the determinations that would attribute other shapes to the Earth, shapes which have not been established by observation, but only deduced from some hypotheses which are thought, given the limitations, to be applicable in the case of some bodies."[45]

Of course, Manfredi was expressing his partisanship with the official thesis of the Academy, but the influence of the atmosphere generated by those who wanted to make new measurements was obvious. From 1733 in different memoirs and for different reasons, there was a clamoring for the attention of the public authorities in an effort to get them to finance expeditions to areas far from Paris. A reading of the Procès-verbaux... of the academic sessions is proof enough that in June 1733 the necessary climate was created at the Academy for it to make a proposal to Maurepas, Minister of the Admiralty, to this end. On June 10, Maupertuis finished reading his memoir, "Sur la figure de la Terre y sur les moyens que l'Astronomie et la Geographie fournissent pour la determiner." In it, after considering the convenience of measuring an arc of meridian on the Equator, he said, "Never has a degree of the Equator been measured and, perhaps, it will still be a long time before this measurement is taken..."[46]

A few days later, on June 23, Godin finished another memoir in which he posed the question again. Six months later we read in the Register of the final academic session of the year, "M. Godin has begun to read a Paper about the merits of a trip to the Equator."[47]

Obviously, the proposal was approved, although no mention of it can be found in the Registers of 1734. The rest of the story is summarized by Maupertuis in the extract of the geodesic operations made in Lapland: "The Academy is thus divided; its own geniuses were not sure, when the King wanted this great question decided, whether it was one of these vain speculations of the kind that sometimes occupied the idleness and useless artfulness of Philosophers, or whether it would have real influence on Astronomy and Navigation."

Further on he writes, "M. the Count of Maurepas, who loves the Sciences and who wants to make them useful for the good of the State, found that this enterprise was to the benefit of both Navigation and the Academy, and this prospect of public utility was worthy of the attention of M. the Cardinal of Fleury. In the midst of War, the Sciences found in him a degree of protection and assistance they would not have dared to hope for in times of thorough Peace."[48]

Below we will see to what an extreme extent economic and political interests stimulated the Crown's contribution to Godin's project. Preparations for the expedition to the Viceroyalty of Peru began in 1734. The following year, after the South American expedition had begun its voyage towards the sea of the Antilles, Maupertuis suggested that the Academy undertake another expedition to measure a degree in what is today Finland. His prestige and his personal friendship with Maurepas simplified the approval of this new project. These two expeditions, together with those that would follow later, constitute the greatest scientific enterprise --in financial and political terms as well as in strictly technical and scientific ones-- undertaken during the first half of the 18th century.

The mere list of names of the men of science mobilized by the Academy is proof that this assessment is no exaggeration: Godin, Bouguer, La Condamine, Juan, Ulloa, J. Jussieu, Verguin, Hugo, Couplet, Celsius, Maupertuis, Clairaut, Camus, Lemonnier, Outhier, Cassini de Thury, La Caille, Maraldi, and others.

Above and beyond the political and scientific interests these projects aroused in the Court and the Academy, the expeditions were perceived by both institutions as being true adventures of modern times. This idea exerted an intense fascination over certain groups associated with the Court and the nobility. Captivated by the very notion of the "voyage," they eagerly followed this gesture of modernity. This was even more so when the adventure was proof of the nation's honor and the prestige of its academicians, that constellation of wise men now haloed by a light greater than their science: the light that emanated from their lofty designs.

The Enlightened Argonauts

How could these expeditions to exotic countries fail to excite interest? Curiosity about other worlds began to form part of the educated mentality; knowledge of these countries' anthropological, ethnographic and natural characteristics began to dominate the "universal" character that the boldest publicists of the Enlightenment already claimed for their European culture. In many drawing-rooms, interest in the gallant adventures of war was now replaced by enthusiasm for the exotic nature of faraway lands and strange social patterns and ways of living. We speak here of that public which, with no specialized education, had taken sides with one or the other of the two antagonists in the controversy, and were now anxious to consume literature on the topic. The second edition of Maupertuis' <u>Examen désinteressé...</u> included an additional text under the title "Histoire du Livre," which recounted the surprising success it had had. There was no doubt: the question of the shape of the Earth was a fashionable topic among those who frequented the most exclusive Parisian salons.

As for the transatlantic adventure, America appeared as an object of interest in itself. Everything to do with the New World was extremely important to the rational work of the Enlightenment. America too formed part of the work of the Creation; once the first stage of conquest, catechism and plunder was over, the most optimistic people proclaimed the need for rediscovery. Europe seemed incomplete, its culture lopsided, without knowledge of America. It was essential to learn about alien cultures. It is not that its riches were no longer of interest; on the contrary, greed was never more rampant, although some of the agents of domination substituted the quadrant for the missal.

The press understood and fed this fascination, eagerly searching out any news that could nourish this entertaining gossip. Papers in Leipzig, Amsterdam, Utrecht, Hamburg, Berlin and other cities published data on the organization, costs, history of the problem and the events of the voyages. Among the contributors we find Pacin, Celsius, La Condamine, Maupertuis and Cassini de Thury. On July 16, 1736, the Gazette litteraire de Leipzig reported that Maupertuis had argued before the Paris Academy of Sciences for the need to make a geodesic expedition to the Kingdom of Sweden. On April 20, 1736, the Gazette d'Amsterdam, an early bird compared to the previous journal, was already telling its readership that the French academics would be assisted by Swedish astronomers. The most surprising and interesting item, however, was the following: on June 9, 1736, the Gazette de Hambourg explained that the six academics who had gone north needed 10 persons to help them and 40 crates to transport their instruments. In addition to Celsius, named by Charles XII to assist with the geodesic operations, it was said that the expectations of the inhabitants of those lands was so great that a large group of wealthy people had joined the enterprise, ready to accompany this peculiar French envoy wherever they went. How could the report in the Gazette d'Amsterdam on September 25, 1736, fail to astonish the readers? "We have received news of Lapland through Sweden, to the effect that Mr. de Maupertuis and his company, consisting of thirty-two persons, have reached the foot of Mt. Kasca.... They have to make a lot of smoke there to keep from being eaten alive by the mosquitos. They live on salmon, ham, and reindeer tongue; and they seem quite pleased with the Lapps."

Three days later, the Gazette d'Utrecht published a letter by Celsius in which he explained that the expedition would be a success in terms of its conclusions as well as on account of the number of issues investigated. Although news of the expeditions that had crossed the Atlantic was delayed because of the difficulty of communications, it finally began to arrive. On October 29, 1737, the Gazette d'Amsterdam reproduced a letter from La Condamine. The physical hardships to which they were subjected were terrible, and the effort expended, heroic. A few months later, on April 1, 1738, the same paper reported that, according to another letter from La Condamine, dated Quito, June 3, 1737, work had ground to a halt because of lack of economic resources. In sum, the subject continued to attract the attention of newspaper editors until the middle of 1739.

But let us return to the nucleus that was most responsive to all these affairs. On April 17, 1735, Voltaire wrote to J. B. N. Formont, poet, brilliant conversationalist and a regular at the Parisian salons: "Know that our argonaut philosophers, have at last left to plot a meridian and parallels in South America. We will finally know what the shape of the Earth is and exactly what a degree of latitude measures. This undertaking will be of service to navigation and will honor France. The Council of Spain has appointed a few junior Spanish philosophers to learn their trade with our own men. If our politics is but the most humble servant of the politics of Madrid, our Academy of Sciences will avenge us. The French win nothing at war, but they measure America."[49]

Voltaire was too interested in the activities of the Compagnie des Indes and the commerce of Cádiz to fail to understand what this revenge he mentioned consisted of. If the signing of the first Family Pact (*Pacto de Familia*) had been interpreted as a sign of weakness in French foreign policy, few were unaware that this peaceful invasion of the Spanish colonies would reap more benefits than those strictly derived from the mere clarification of the shape of the Earth. Let us leave aside for the moment the economic interests which, as we shall see, was present at every moment of the organization of the voyage. For the most lofty European spirits the assimilation of the cultural values of the indigenous population as opposed to religious fanaticism formed part of a new strategy of domination, thereby making it essential to replace the Huguenot and the Jesuit with the scientist and the naturalist--new ambassadors disposed to "westernize" and "think" the cultures of the "other."

At the same time that he admired the Anglo-Saxon commercial genius, Voltaire harshly criticized the brutal attempts to dominate exercised by the colonial European powers, among whom Spain occupied first place on his particular list of *bêtes noires*, scourges of humanity. The relation Spain had established with its American possessions was limited, according to the French philosopher, to the blatant plunder of riches and the systematic cultural destruction of civilizations that had been reduced to a state of barbarity. The impression La Condamine transmitted soon after arriving in Portobelo is no different: "In sum, after fifteen days of sailing we have reached Cartagena, where we have met two fellow voyagers appointed by the Spanish Court to assist us with our work, and they are very well prepared to help as geometricians and astronomers. I don't know what awaits them on their return, but as soon as they were chosen, they suddenly were promoted from cadets to first lieutenants. This is how Spain is beginning to treat people who bring to Peru the Love of the Physics only in their baggage. In this regard, I can tell you that the customs agents were quite surprised at the nature of our cases.

Although a Frenchman has not been seen in Portobelo for 19 years, they still remember the ones who went to the South Sea and took nothing (in their luggage) except Quadrants and Barometers."[50]

We will not comment on the pride with which La Condamine attempts to reveal to Voltaire the differences in their missions. Like many of their contemporaries, they both thought that the dynamic of cultural development could be explained by the tension existing between the will for personal development and the obstacles erected by external and individual nature. The Peruvian expedition provided plenty of opportunities for reflection. The clash of cultures excited curiosity and aroused sympathies: peoples born to dominate a continent had been reduced to slavery. Rebellion from the ethical and anthropological point of view was not only justifiable but necessary. While La Condamine bent to the task of triangulating South America, Voltaire composed poems on the American theme: both were considered carriers of the "lumière" that would remove the obstacles referred to above:

> My muse and his compass are both in Peru:
> He appraises, examines; and I paint nature.
> I sing of the countries he measures:
> Which of us is crazier?[51]

These verses were not the only Voltairian contribution to the immortality of scientific pursuits. In the same year his play Alzire ou les américains opened to great success. On January 29 he wrote to C. Ph. Berger explaining the reasons that had moved him to write it: "The scene is Peru, gentlemen, a place little known to poets. La Condamine measures this country, the Spaniards exploit it and I sing of it."[52]

In his Essai sur les moeurs (Basel, 1754), he had written a merciless exposé of the excesses and exploits of Pizarro and Cortés. Now, through the description of the characters' passions and contrasts, he demonstrated the supreme wisdom of a spirit free of fanaticism. The action takes place in Lima. The people, who despair under Spanish domination, find a leader for rebellion in Zamora. His fiancée, Alzire, is forced to be baptized and to marry Guzmán, the country's tyrannical governor. This provokes Zamora's rage, and after hatching a new plot, he takes Guzmán's father prisoner. Before being executed, his son, who has been mortally wounded, recognizes his sins and repentantly hands over Alzire and the government of the country to his opponent. Zamora then understands the greatness of a religion that teaches forgiveness and converts to Christianity. The plot and the message of the play moved the audience. One of them, Pierre Robert Le Cornier de Cideville, could not resist the temptation to send Voltaire some impassioned verses:[53]

Corrupt mortals, some vice
Always leads you to seek a New Universe;
First your Greed
Dares you to cross over there, to the infernos
To seize the hateful and perverse Gold,
Instrument of your injustice.
Leave this Precipice
Because your Rashness will offend Heaven.
Our latest voyagers, crazier than their ancestors,
Will discover in the New World
If this Earth is Elliptical or Round.
We never travel to be virtuous.
In a Dramatic Play
Voltaire disturbs us with more flattering Treasures:
Our ambition, our Politics,
Our brilliant obsessions oppose the customs
Of virtuous America,
And in a public lesson
He corrects us by moving our hearts.

It is exciting to see how an enterprise of strictly scientific character --in principle-- became a fashionable topic among the cultivated elite. In fact, in the configuration of the enlightened mind, "the voyage," the encounter with "the other," began to be the stimulus for reflections on his own identity. And there was no doubt that it would be one of the most important scenarios for the already existing tension between classicism and Romanticism. A mood of pre-Romantic stripe is already apparent in A. de Ulloa when, using clearly Romantic resources --rather more literary than philosophical here-- he attempts to move his readers to tears with a description of Lima before the earthquake of 1746: "...I will tell how it was, its now eclipsed glories, its majesty, its riches, and all that which made it famous in the world, the form we knew it in; so that its memory will multiply the pain of its fatal contretemps in our souls."[54]

Such attitudes permit an understanding of the "voyage" as a universal undertaking and as a national glory, as the heritage of a classical world and as the new world that astounded the 18th century Europe, as an undertaking of rightfulness and virtue, and as an escapade of adventure and the unforeseen.

Scientists and the enlightened nobility shared this multifaceted interest in other worlds that were strange to them, stretching shining bridges between distant worlds; and their enthusiasm was added to that of the French state itself. The Academy's project would soon become a state enterprise.

The Expedition to Lapland

On January 14, 1736, Mairan wrote to Delisle to inform him about what was happening at the Paris Academy of Sciences. "What's new right now at the Academy is a project of M. de Maupertuis, Clairaut, Le Monnier (son), etc., who are preparing to carry out operations in Sweden corresponding to the operations of our Astronomers in Peru, planning to leave around next March. As for the rest, we received news of our Peruvians from Martinique and the island of Santo Domingo, when they were about to embark for Portobelo; this was three or four months ago."[55]

In fact, on June 8 of the same year, 24 days after the departure of the ship that was carrying the "Peruvian" expeditionaries, Maupertuis had agreed, at Fontenelle's suggestion, to measure an arc of meridian in the north of Europe. Before a year had passed, on May 2, 1736, Maupertuis, Clairaut, Lemonnier, Camus and Outhier --who would be joined later by the Swedish scientist Celsius-- left the port of Dunkirk for Sweden. Eight months later, on January 9, 1737, their work was finished and they were on their way back to France.[56]

An atmosphere of maximum tension accompanied the decision to organize this new project. Confusion was at a high level; the testimonies we have been left are eloquent. While preparations were being made for the expedition to the north, Maupertuis wrote to his old teacher, J. Bernoulli, to tell him about his plans and ask his advice. The famous mathematician from Basel did not delay in replying: "But, tell me, sir," Bernoulli wrote on May 8, 1735, "do the observers have any predilection for one or another of the sentiments? Because, if they are inclined to consider the Earth flattened, they will surely find it flattened; on the contrary, if they are convinced the Earth is elongated, their observations will not fail to confirm its elongation: the step from the compressed spheroid that makes it elongated is so imperceptible that it is easy to err if one wants to err in favor of one opinion or the other. Even if the observations go against me, I have prepared a suitable response that will shield me from any objection; so, I stand firm and wait for the result of the observations."[57]

Bernoulli cast a shadow of doubt over the results of the expedition even before it was made. The commitment of Maupertuis and Clairaut to Newton was so accentuated that it presupposed a voluntary bias in the observations. The framework of objectivity reserved to science was in jeopardy. Everyone was convinced of his own right; and when such convictions were threatened, the opponent's honor was questioned: "They say that he (M. Celsius) is even more obstinate than Maupertuis on the System of Newton and that he went on this expedition completely determined to prove the Newtonian hypothesis."[58]

So Bernoulli was not the only one to express doubts about the possibility of resolving the polemic through scientific observation. Soon we will see new testimony about the extremely high-strung atmosphere that prevailed in Paris. But first let us review the essentials of Maupertuis' expedition.

The geodesic and astronomical operations were performed in the Gulf of Bothnia, using one of the islands in the mouth of the Tornea river, called Swentzar, as a *base*. The cold, all in all, was not the chief obstacle they had to face. Listen to what Celsius recounted to Delisle about the punishments of the polar vicissitudes. "The trigonometrical operations have lasted all summer and have caused us a lot of trouble, both because of having to climb rugged mountains with the instruments and cross uninhabited forests and lakes, as well as having to descend violent cascades among rocks that frequently capsized the boat. But a prodigious number of "Comrades" has bothered us more than any other thing. These insects have bitten us on our faces and hands most cruelly."[59]

It still seems paradoxical that mosquitos were the worst torment for the expeditionaries of the north, while the worst for the men who went to the South American equator were the violent storms and glacial cold they encountered on the Andean peaks.

The triangulation was achieved using a heptagon formed by 8 triangles between the cities of Tornea and Kittis. The description of the operations carried out by Maupertuis shows us the ample number of precautions taken in each phase of the work. Once it was finished and a first value for the degree obtained, the chief of the expedition recounts: "The length of the arc we have measured, which differed so much from what we ought to have found following the measurements from the book of the magnitude and shape of the Earth (here he is obviously referring to J. Cassini's book), is surprising: and in spite of the incontestability of our methods, we decided to make more rigorous verifications of all our work."[60]

Since the resulting degree was exaggeratedly larger than that predicted by Cassini, Maupertuis explains that they repeated all the observations as many as twelve times and that the maximum dispersion did not exceed 54 fathoms on an arc whose amplitude was 55,023.5 fathoms. Still not satisfied with previous verifications, they presumed that on the first two angles of each triangle they had committed an error of 20" and that on the third the error had amounted to 40". The calculations derived from such "extreme assumptions can yield an error of only 54½ fathoms."[61]

The first observations of the star *alpha*-Draconis gave an amplitude of 57'27" for the arc; verified with three new series of measurements using *delta*-Draconis it was found to be 57'30"30". Repeating again and calculating the average value of all the amplitudes, they finally arrived at an arc of 57'28''45''' amplitude, 55,023.5 fathoms of length and, therefore, a degree of 57,437 fathoms. The conclusion was clear: "From the measurement between the amplitude deduced from *delta* and the amplitude from *alpha*, we find that the amplitude of the arc of meridian we have measured between Tornea and Kittis is 57'28"3/4, which, compared to the length of 55,023½ fathoms of this arc, gives the degree which crosses the polar circle as 57,437 fathoms, greater by 377 fathoms than that measured by M. Picard between Paris and Amiens, which was 57,060 fathoms.

"But it is necessary to point out that as the aberration of the stars was not known in M. Picard's time, he did not make any correction, and that if one adds the corrections for the precision of the equinoxes and the refraction which M. Picard had underestimated, the amplitude of his arc is 1°23'6''30''', which compared to the length of 78,850 fathoms makes the degree 56,925 fathoms, shorter than ours by 512 fathoms. If one does not take account of the aberration, the amplitude of our arc would be 57'25", which compared to its length would give the degree 57,497 fathoms; larger by 437 fathoms than the degree which M. Picard had measured of 57,060 fathoms without aberration. In sum, our degree with aberration differs by 950 fathoms from what it ought to be, following the measurements which M. Cassini has established in his book De la grandeur et la figure de la Terre; and it differs from him by 1000 fathoms without accounting for aberration.

"From which it can be seen that the Earth is flattened at the poles."[62]

There was no room for doubt. The quality of the work was impeccable. The magnitude of the difference must have embarrassed the partisans of the theory of the oblong Earth when at a solemn public session on Wednesday, November 13, 1737, Maupertuis settled the question definitively in favor of Newton's thesis. The response of some members of the Academy could not have been more discouraging. "But before our departure, the Academy of Sciences had in some way taken sides on this affair. Our measurement gave the opposite result and made the Earth flattened. Then, when we arrived we found great contradictions: Paris, whose inhabitants could not remain indifferent to anything, was divided into two camps; some took our side, and the others believed that the national honor was at stake if the Earth were allowed to assume a form that had been imagined by an Englishman or a Dutchman. They tried to spread doubts about our measurements: as for us, we attacked the measurements that had been made in France: the disputes grew, and the disputes soon gave birth to injustices and made enemies of people. The Ministry, which had spent a great deal of money on the measurements of the French meridian, did not want to believe that these measurements were in the end useless."[63]

With the results of La Condamine's expedition known, this passage summarizes the violence of the discussions and confrontations that had taken place in the Academy. Fortunately, we can still reconstruct some of it from the correspondence between Voltaire and Delisle and from some letters exchanged between Maupertuis and Celsius in the months following the return of the northern expedition. We think the beauty of the documentation and the importance of the theme justify our extensive citations in the pages that follow.

After the publication of the Discours sur les differents figures des astres, the internal tension in the Academy had steadily increased. Voltaire, who had gone to Newton's funeral in 1727 and had already had occasion to openly declare himself Newtonian, hastened to write to him asking advice about the inclusion in his Lettres philosophiques of the passages in which he tries to compare the philosophies of Newton and Descartes: "I am your follower and I place my profession of faith in your hands."[64]

The Lettres philosophiques were probably prepared during Voltaire's stay in London between 1727 and 1728, but they did not appear in his French edition until April 1734. The scandal provoked by its contents, which went so far as to include the burning in public of several copies by the public executioner, obliged him to go into exile in the mansion at Cirey, near Lorena, which belonged to his friend Grabielle-Emile Le Tonnelier de Breteuil, the Marquise of Châtelet. The same month in which the Lettres appeared, he wrote to Maupertuis explaining the reaction and his main suspicions about the instigators of the persecution against him. "It is these English letters," wrote

Voltaire, "which drive me into exile. In truth, I think that some day they will be very ashamed for having persecuted me on account of a work that you corrected. I'm beginning to think it is the partisans of the vortices and innate ideas who are behind the persecution. Cartesians, Mallebranchists, Jansenists, they are all against me. But I await your support. It is necessary, please, that you become head of the sect. You are the apostle of Locke and Newton...."[65]

With pleasure Maupertuis assumed the role that Voltaire had already imputed to him since 1732. Both of them, together with Clairaut and La Condamine, using all the means at their disposal in an almost obsessive manner, began a no-holds-barred struggle against official and academic schooling. Voltaire wrote to La Condamine in 1734, "If the court was composed, Sir, of excellent philosophers, I would not be very angry at having been condemned, but I think these venerable magistrates have only a second-rate understanding of Newton and Locke. Therefore, they are for me no more respectable than those persons who on another occasion passed a decree in favor of Aristotle's physics, who defended giving the emetic. They always have the best of intentions."[66]

A group began to form around Mme. Châtelet at the castle of Cirey--Voltaire, Maupertuis, Koening, La Condamine, Clairaut, Algarotti. Stimulated by a broad network of correspondents --Euler, 'sGravesande, Musschenbroek, Cramer, Jurin, Celsius, Mignot de Montigny, Formont, and so on-- they formed a Newtonian front dedicated to the renewal of French culture. While Voltaire, through his letters, spread news beyond national borders about the intransigence and ignorance within the French circles of power, Maupertuis started a battle in the Academy in which irony and a sense of ridicule were his principal weapons. L. Anglivel de la Beaumelle, his most trustworthy and committed biographer, wrote, "M. de Maupertuis was aware of the methods of his adversaries, who obstinately resisted the tyranny imposed on them by evidence. To avenge Newton and himself, he decided to start a revolution through a kind of artifice, a revolution which pure reason would have accomplished only too slowly. On assembly days he would invite several young Newtonians to supper, men who were full of good spirits, self-confidence and good arguments, whom he was teaching at the Louvre. He launched them against the old academy, which from then on could not open its mouth without being besieged by these confirmed, ardent young defenders of the theory of attraction. One would wear out the Cartesians with clever arguments, another with demonstrations. One, ready to capture the absurd, would copy the adversaries' gestures, expressions, and tone of voice, responding to their arguments while mimicking their manners. The other, guffawing at the changes they were making in the old system, held that the system was defective. This little group was assisted, at times, by the caustic irony of its leader."[67]

Thus was scandal provoked by Clairaut, La Condamine and "son chef" Maupertuis in the stuffy academic atmosphere. The fourteenth letter of Voltaire's repressed work, "On Descartes and Newton," seems to have been published in the same spirit--a "revoltairian" spirit, if we may. "A Frenchman who goes to London finds things quite changed in philosophy, as in everything else. He left the world full; he finds it empty. In Paris the Universe is composed of vortices of subtle matter; in London, you don't see any of this (...). In Paris, you would think the Earth looks like a melon; in London, it is squashed at both ends (...). Descartes assures us that matter only has extension. Newton adds solidity to that. We have here some furious contradictions. *Non nostrum inter vos tantas componere lites*."[68]

The reading of the conclusions of the voyage to Lapland on November 13, 1737 at the Academy did not meet with a receptive climate, as we have explained. A silent majority closed ranks around the Cassinis and began a campaign of harassment that soon developed into personal insults and discrediting. Two letters by Mme. Châtelet supply ample details. "In this country," she wrote to F. Algarotti on January 10, 1738, "the Newtonians are considered to be heretics. Surely you know about M. de Maupertuis' return: the accuracy and elegance of his work surpass everything people said could be expected. The difficulties he experienced are worthy of Charles XII. I assure you that your little Italian heart would be very displeased. The reward for so much precision and so many ordeals has been persecution. The old academy has risen up against him, M. de Cassini and the Jesuits who, as you know, have found the elongated Earth in China (this refers to the observations of P. Gaubil) agree with them; they have persuaded ignorant people that M. de Maupertuis didn't know what he was saying: half of Paris, perhaps three quarters, believe them. They have tried to erect a thousand difficulties to prevent the printing of the account of the voyage and its operations; I don't know if they will succeed. They have given such mediocre pensions that M. de Maupertuis has refused his, and has asked that it be divided up among his colleagues: in sum, they don't want Newton to be right in France."[69]

The same day, in another letter addressed to Maupertuis himself, she emphasizes the generally institutional character of the reaction. "I haven't lost hope of seeing an act of parliament against you. I believe that these are the circumstances to which the denial of Newton's Elements of Philosophy in France must be attributed. We are heretics of philosophy."[70]

In fact, spurred on by circumstances and the not very convincing book published by his friend F. Algarotti, Il newtonianismo per le dame (1737), Voltaire decided to follow up what he had already published in the Lettres philosophiques with a new book to popularize Newton's philosophy. At the time his intentions were clearly perceivable by any attentive observer; there was no better topic than the Newtonian crusade. The Parisian academic Etienne Mignot de Montigny wrote to him, "Today you wish to smash all the vortices of Descartes and invite the French, whom you still love, to prefer the demonstrations of Newton over the sublime and irrelevant dreaminess of this mechanistic philosopher."[71]

And, in fact, the Eléments de la philosophie de Newton mis à la portée de tout le monde (1738) unleashed new persecutions that forced it to be hastily published in Amsterdam.[72]

While Cassini schemed to see to it that the results of Maupertuis' operations did not appear with the official backing of the Academy, and verses about supposed amorous escapades of Maupertuis in Lapland were circulated in scandal sheets,[73] Maurepas himself tried to buy the silence of the expeditionaries by offering them pensions so low as to be insulting. Voltaire commented in January 1738, "It has occurred to some people in Paris who are incapable of even knowing what your worth is, to write satirical songs about you when you worked in the polar circle for the honor of France and of human reason....

"I am convinced that when you rejected the pension of twelve hundred pounds, which you generously divided up among your companions on the voyage, you must have seemed to the Minister to be a more noble than a discontented spirit."

Voltaire then began and continued for several years to bestow titles on Maupertuis such as "marquis au cercle polaire," "son cher aplatisseur de ce globe," "Sir Isaac Maupertuis," or to put headings on his letters like this one from a letter written in 1740, "La 3^{e} année depuis la terre aplatie." To the letter we have just been quoting, he added, "Remember that they supported a thesis against the circulation of blood. Dream of Galileo, and take comfort."[74]

Neither Voltaire nor Mme. Châtelet were exaggerating in their assessment of the circumstances. Nothing is more eloquent than Maupertuis' own testimony when he finally decided to leave Paris in order to avoid the persecution aimed against him. "It has been some time since I left Paris and came to Brittany; I recognize that the injustices I have suffered are in part the reason behind this and now that my book has been printed, I have gone and left everything to whatever the fatuous and ill-intentioned want to say.... I have not told you everything I have had to suffer since my return, I am not any more satisfied with the Academy than with the rest of them, and some of our companions, after being paid a disgraceful pension, have not given any more thought to our measuring than a workman does after he has been paid. There has not been a single circumstance since my return that has not been grievous for me."[75]

Again we hear mention of the topic of the pensions which compromised the impartiality of the Admiralty itself and of its chief, the Count of Maurepas. The dejected tone of Maupertuis' letter should not mislead us about his true aggressive and bold temperament. He went to Brittany only after assuring himself that an edition of his book would be printed in Amsterdam, at the same time that the Paris edition was presumably being delayed by hindrances.[76] But that is not all. By the end of the year, he wrote two new anonymous papers which ridiculed, in different ways, the work done up until then by the Cassinis and their co-religioners. These were the Examen désinteressée des differents ouvrages qui ont été faits pour déterminer la figure de la terre (Oldenbourg, 1738) and the Anecdotes physiques et morales (no place of publication given, 1738). Two years later he published yet another pamphlet titled Lettre d'un horloger anglois à un astronomie de Pékin (1740).[77]

While Maupertuis was preparing these publications, whose principal objective was to discredit Cassini by using irony --unlike the case of the Discours..., they were publishing successes with large sales-- he encouraged Celsius, supplying him with sufficient information, to edit a rigorous diatribe against the whole set of geodesic operations conducted in France.

"You would do well," he wrote to Celsius on January 31, 1738, "to present to the public the oversights and omissions of M. Cassini on a matter in which he wants to believe that we are the ignorant ones. I don't doubt that you have found plenty to ridicule in his book. Nothing could be poorer than the instruments he used, nothing cruder than his observations. An error of 41" in the amplitude concluded using different stars for the arc between Paris and Dunkirk; stars observed for a whole month without any aberration perceived; all this proves well that his "giro" (of 180°) did not do him much good, and did not give him the true altitudes of his stars.... There is one more terrible reproach; he did observations in Paris to conclude its Amplitude, and using the star he chose there was a difference of 57" between his father and himself; it was the right moment to have to consult with the others. This oversight of not having observed the same stars in Paris when he had all the resources to do so is unforgivable. But he forgot to say (page 8) that in Paris he observed the same stars that he had observed in Collioure, so why doesn't he mention at all that the shapes they give for the earth are very different from what he established? I believe that all one can make of this is that he never believed the day would arrive when people would want to know better about the shape of the Earth, and that he believed he would be free of ever being bothered about it...."[78]

In fact, Cassini's book could not stand up to the detailed analysis made by A. Celsius from an eighteen-year-perspective in De observationibus pro figura telluris ada in Gallia habitis... (Uppsala, 1738). The last words of the booklet are clear and conclusive: "Therefore, I hope the wise and sensible reader has realized that the Cassinis' observations, both the celestial ones and the terrestrial ones, principally those conducted in the South of France, are inaccurate, and so therefore is the problem of the shape of the Earth."[79]

Cassini was quick to reply. Given the impossibility of rebutting the avalanche of incongruities and inaccuracies pointed out by Celsius all at once, he appealed to the *esprit de corps* and the very honor of the members of the Academy. "In the first place, I would answer him that the Shape of the Earth he has deduced from the Observations of the North would have no basis compared with those made in France, if one attributed such gross errors to them as he imputes to my father and me. Errors that fall upon all the rest of the astronomers of the Academy of Sciences who worked together with us on the description of the Meridian of Paris and who are very well versed in the observations."[80]

But undercover, with no qualms and going beyond what could be published in a specialized memoir, his maneuvers against Celsius were aimed at discrediting his image: "I am annoyed that my dissertation has provoked M. Cassini into trying to make me hated in France, as if I were someone who wants to discredit all the work of the French Astronomers.... M. Cassini is really the aggressor because he has attacked our observations in the Academy and moreover has written in all the journals about the inaccuracy of our operations."[81] The scientific and academic debate was followed by personal confrontation, a struggle in which each party had his own interests and allies.

The weakness of the arguments used by Cassini de Thury, however, were well understood by the Jesuits of Memoires de Trévoux. As if it were a matter of discerning the honor of two men in disagreement over matters of opinion, they said: "M. Cassini...responds with the justice and intelligence of a wise man, and all the courtesy of a virtuous man who is not obsessed with any system, who is not biassed against any idea, who seeks nothing but the truth."[82]

After all we have recounted here, we do not believe it necessary to discuss the text. The magnitude of the contradictions, both scientific and personal, were so important that there would be no truce until the definitive consolidation of Newton's thesis. With the replacement of Fontenelle as Secretary of the Academy on December 22, 1740, a cautious shift in direction began that placed the Institution in a position to confront the new times. In the Histoire de l'Academie royale des Sciences for 1740 (published in 1742), Mairan wrote: "Whether the Earth is a spheroid in this sense or that, it will always be such a small difference that this question seems more peculiar than important; but it has contributed to the undertaking of exploits whose importance is more notable, and whose usefulness is more obvious."[83]

With the publication in Suite des Memoires de l'Academie Royale des Sciences année M.DCC.XL, of the new achievements made by Cassini de Thury and La Caille in France, the matter was partially resolved.[84] Voltaire was able to write to Maupertuis and say, "I congratulate you, Sir, for having flattened the Earth and the Cassinis."[85]

The first French Newtonian, however, after so many years of polemic, accepted the invitation of Frederick II of Prussia to take on the Presidency of the Berlin Academy. We cannot close this chapter without recalling a text of Voltaire. With exquisite irony, he included these lines in his Siècle de Louis XV (chapter XLIII) on all the disputes relating to the shape of the Earth: "The journeys to the end of the world to corroborate a truth that Newton had proved in his laboratory have left doubts about the accuracy of measuring."

In 1741 Maupertuis, who knew how to take advantage of the public exposure generated by this dispute, and how to monopolize the success he should have shared with the rest of his colleagues, had a portrait painted by R. Tournière, on which Voltaire wrote the following verses:[86]

This uncertain globe he measured
Is a monument to his glory;
His destiny, to fix the shape of the World
In order to enjoy and illuminate it.

NOTES

1. An excellent analysis of the issues under discussion can be found, for instance, in P. Cassini, El universo máquina, Barcelona, 1971, and in J. Ehrard, L'idée de nature en France dans la première moitié du XVIIIéme siècle (Paris, 1963).

2. J. R. D'Alembert, Discurso preliminar de la Enciclopedia (1751). The quote comes from the Spanish edition of Consuelo Bergés and Antonio Rodríguez Huéscar (Madrid, Aguilar, 1974), p. 113.

3. See Ch. C. Gillispie, "Fontenelle and Newton," in I.B. Cohen (ed.), Isaac Newton's Papers and Letters on Natural Philosophy, 2nd edition (Cambridge, Massachusetts, 1978), pp. 427-443.

4. Voltaire, "Sobre Descartes y Newton," in Cartas filosóficas (Madrid, 1976), pp. 117-122. Edition prepared for the Editora Nacional by Fernando Savater.

5. Fontenelle, "The Eloge of Sir Isaac Newton" (London, 1728), in I.B Cohen (ed.), Isaac Newton's Papers..., op. cit., pp. 453-454. The French version, "Éloge de M. Newton," was included in Hist. 1727, pp. 151-172.

6. All the citations from Voltaire's correspondence are from the edition of his complete works, The Complete Works of Voltaire (CWV), at the Institut et Musée Voltaire, Geneva. University of Toronto Press. Each letter bears an official file number consisting of the letter D followed by a number. We will only mention this number, as is customary. The specific text to which this footnote corresponds is from a letter written to La Condamine on June 22, 1734. D. 759.

7. D'Alembert, Essai sur les élements de philosophie ou sur les principes de connaissances humaines. Paris, 1759. An interesting analysis of the theme in hand can be found in Th. L. Hankins, Jean D'Alembert. Science and the Enlightenment (Oxford, 1970). See especially pp. 109ff.

8. A. Maury, L'Ancienne Académie des Sciences (Paris, 1864), p. 55.

9. J. T. Desaguliers, "A Dissertation concerning the Figure of the Earth," in Philosophical Transactions, 33, No. 386, 387 and 388, pp. 201-222, 239-255, 277-304 and 344-345 (1724-5). On these memoirs see P. L. Maupertuis, "Examen des trois dissertations que monsieur Desaguleirs a publiées sur la figure de la Terre," in Examen desinteressé des differents ouvrages qui ont été faits pour determiner la figure de la terre (Oldenbourg, 1738).

10. J. F. Lalande, Bibliographie Astronomique (Paris, 1803), p. 394. The same impression is given in F. Weidleri, Historia astronomicae sive de ortu progressu astronomiae, (Wittemberg, 1741).

11. P. L. Maupertuis, Discours sur les differents figures des astres, où essaye d'expliquer les principaux phénomenes du Ciel, in Oeuvres (Lyon, 1756), I, pp. 79-170. The quote is on p. 103.

12. P. L. Maupertuis, Discours..., op. cit., p. 121. In the memoir "Explication et Analise...", op. cit., read in the Academy in 1733, Maupertuis declared: "In no way am I examining if this principle agrees or disagrees with sound philosophy; I am speaking of attraction here as a Geometer." Reg. 1733, p. 42v.

13. The article was "Sur le lois de l'Attraction," in Mem. 1732, pp. 343-362. Hist. 1732, pp. 112-117.

14. Voltaire to Maupertuis; Fontainebleau, November 3, 1732. CWV, D 534. The same idea was later included in Elements de la Philosophie de Newton (1738). See P. Brunet, Maupertuis. Etude biographique (Paris, 1929).

15. Hist. 1732, p. 112.

16. P. L. Maupertuis, "Sur la figure de la Terre et sur les moyens que l'astronomie et la Geographie fournissent pour la déterminer," in Mem. 1733, p. 156 and Reg. 1733, p. 116.

17. Celsius to Delisle; Paris, 21.03.1735. Archives Nationales (Paris). Arch. Nat., Marine, 2JJ63, No. 25[b].

18. Hist. 1732, p. 131.

19. Cited by J. Ehrard, L'idée de Nature..., p. 152.

20. D'Alembert, Discurso preliminar..., pp. 111-112.

21. Jean Bernoulli, "Essai d'une nouvelle Physique céleste, servant à expliquer les principaux phenomènes du Ciel, et en particulier la cause physique de l'inclinaison des Orbites des Planètes par rapport au plan de l'Equateur du Soleil," in Opera Omnia, III, pp. 354-355. The text was also cited for its importance in I. Todhunter, History of the Mathematical..., op. cit., I, p. 116. The same volume contains another memoir by Bernoulli presented at the annual meetings held by the Academy. This work begins with the following phrase: "Perhaps it is surprising that I dare to bring the celestial Vortices onstage, in an epoch when various Philosophers, particularly English ones, consider them to be purely chimeras and only speak of them with the greatest contempt," in "Nouvelles pensées sur le systême de M. Descartes et la manière d'en deduir les Orbites et les Aphèlies des Planètes," Opera Omnia, III, pp. 134-4.

22. P. Brunet, L'introduction..., op. cit., 272ff.

23. Montucla, Histoire des mathématiques, 4 vols., Paris (1799-1802), IV, p. 143. The same opinion is expressed in I. Todhunter, History of the mathematical..., op. cit., I, p. 115.

24. Memoires des Trevoux, 35, pp. 988-1002 (1735). See also the Journal des Sçavants (1735), pp. 45-52. The memoir by D'Anville which was the subject of the commentary is Proposition d'une mesure de la terre, dont il resulte une diminution considerable dans sa circonférence sur les paralleles (Paris, 1735).

25. D'Anville, Mesure conjecturale de la Terre sur l'Equateur, en consequence de l'étenduë de la Mer du Sud (Paris, 1736).

26. M. Bellin, "Remarques de Monsieur Bellin Ingenieur au dépost des Cartes et Plans de la Marine, sur un petit Ecrit, qui a pour titre: Réponse de M. d'Anville. Geographe du Roi au Memoire envoyé à l'Académie Royale des Sciences, contre la Mesure conjecturale des degrés de l'Equateur, en conséquence de l'étendue de la Mer du Sud," in Memoires des Trevoux, 39, p. 87 (1739). Another memoir favorable to Cassini's thesis is P. Gramatici, "Dissertatio astronomica de ratione corrigiendi typos et calculos eclipsium solis et lunae, mapparumque geographicarum constructiones, ab astronomis et geographis hactenus ad hibitas, in hypothesis telluris sphaericae cum ista reapse sit figurae sphaericoidalis," in Commercium litterarium in rei astronomicae incrementum communi consilio instituendum (Nuremburg), 1734. See J. F. Lalande, Astronomie, op. cit., p. 397.

27. Marqués de Poleni, "Remarques sur le livre de la Figure de la terre," in Journal historique de la République des Lettres, January-February 1733.

28. J. Cassini, "Reponse aux Remarques qui ont été faites dans Journal historique de la République des Lettres sur le Traité De la Figure et de la Grandeur de la terre," in Mem. 1732, pp. 497-513.

29. An extensive commentary of most of these works in their relation to different contributions by Maupertuis can be found in P. Brunet, Maupertuis. L'oeuvre et sa place dans la pensée scientifique et philosophique du XVIIIe siècle (Paris, 1929), pp. 89-166.

30. L. Godin, "Méthode pratique de tracer sur terre un parallèle par un degré de latitude donné et du rapport du même parallèle dans le sphéroïde oblong et dans le sphéroïde aplati," in Mem. 1733, pp. 223-232.

31. L.Godin, "Nouvelle méthode de trouver la hauteur du pôle," in Mem. 1734, pp. 409-416.

32. La Condamine, "Description d'un instrument qui peut servir à déterminer sur la surface de la terre tous les points d'un cercle parallèle à l'équateur," in Mem. 1733, pp. 294-301.

33. A. C. Clairaut, "Détermination géometrique de la perpendiculaire à la méridienne tracée par M. Cassini avec plusieurs méthodes d'en tirer la grandeur et la figure de la terre," in Mem. 1733, pp.

34. P. L. M. Maupertuis, "Sur la fugure de la terre et sur les moyens...", op. cit.

35. J. Cassini, "Méthode pour déterminer si la terre est sphérique ou non, et le rapport de ses degrés entre eux, tant sur les méridiens que sur l'equateur et ses paralléles," in Mem. 1735, pp. 255-261.

36. These memoirs are: J. F. Cassini de Thury, "Des opérations géométriques que l'on emploie pour déterminer les distances sur terre et des précautions qu'il faut prendre pour les faire le plus exactement qu'il est possible," in Mem. 1736, and A. C. Clairaut, "Sur la mesure de la terre par plusieurs arcs de méridien pris à differentes latitudes," in Mem. 1736, pp. 111-120. To these memoirs we must add, as a continuation of those already cited, another one published in the same volume by Cassini de Thruy, "Précautions que l'on doit prendre pour observer le plus exactament qu'il est possible la hauteur des étoiles," in Mem. 1736.

37. Maupertuis, "Méthode pour trouver la déclinaison des étoiles," in Mem. 1736.

38. Maraldi, "Méthode de trouver la hauteur du pôle et la déclinaison des étoiles, qui n'est pas sujette à la refraction," in Mem. 1736, pp. 43-49.

39. D. de Mairan, "Problème astronomique: trouver la hauteur du pôle indépendament des réfractions, lorsque cette hauteur n'est pas au dessous de 25 ou 30 degrés, par le moyen d'une étoile qui passe ou qu'on seint passer par le zenith," in Mem. 1736, pp. 147-166.

40. P. L. M. Maupertuis, "Sur la figure de la terre", in Mem. 1736, pp. 302-312. We think it is not outside our scope to reproduce the reasoning followed by Maupertuis to find the formula mentioned in the text. As elsewhere, we will reproduce it by summarizing the contents of the memoir step by step. We will provide the following definitions:

CA = 1, radius of the equator.
CP = m, semiaxis of rotation.
sinEKA = s, sine of the latitude of E.
sinFLA = t, sine of the latitude of F.
EM, ordinate of E.
Ee = N, degree of latitude on the surface.
Ef = M, degree of latitude on the surface.
$y = m(1 - x^2)^{1/2}$, being the ellipsoidal figure.
$EK = m(1 - x^2 + m^2x^2)^{1/2}$, normal to E.
$EG = (1/m) / (1 - x^2 - m^2x^2)^{3/2}$, radius of the envelope
a, polar flattening.

In the triangle EKM we have:

$$\frac{1}{s} = \frac{m(1-x^2+m^2x^2)^{1/2}}{m(1-x^2)^{1/2}} \quad \Rightarrow \quad x^2 = \frac{1-s^2}{1-s^2+m^2x^2}$$

Substituting EG for the value x^2 in the expression, we obtain:

$$EG = \frac{1}{m}\left(\frac{m^2}{1-s^2+m^2s^2}\right)^{\frac{3}{2}}$$

By the same reasoning:

$$FH = \frac{1}{m}\left(\frac{m^2}{1-t^2+m^2t^2}\right)^{\frac{3}{2}}$$

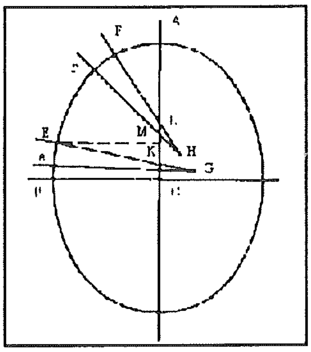
To simplify these formulas, we take a = (1 - m²)/2, since a is assumed to be very small, so that:

$$(1-s^2+m^2s^2)^{-3/2} = [1-(1-m^2)s^2]^{-3/2} \simeq (1-2as^2)^{-3/2} \simeq 1+3as^2$$

then,

$$EG = m^2(1 + 3as^2)$$
$$FH = m^2(1 + 3at^2)$$

Given that the angles in G and in H are one degree, the sectors eGE and fHF are similar and, therefore, the radii will be proportional to the arcs. That is:



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$$\frac{Ee}{EG} = \frac{Ff}{FH} \Rightarrow n+3Nat^2 = M+3Mas^2$$

Hence:

$$a = \frac{N-M}{3Ms^2-3Nt^2}$$

Maupertuis concludes by seeking a formula that allows comparison of a degree measured at any latitude with another degree determined on the equator. If M is the latter degree and N the degree obtained on the latitude, the formula found was:

$$N-M = 3mM\times\sin^2L + \frac{15}{2}\times m^2M\times\sin^4L$$

The same theme is treated in another memoir, "Sur la figure de la Terre," in Mem. 1735, pp. 98-105.

41. A. C. Clairaut, "Sur la mesure de la terre par plusieurs arcs de méridien pris à differentes latitudes," in Mem. 1736, pp. 111-120.

42. P. Bouguer, "De la manière de determiner la figure de la terre par la mesure de degrés de latitude et longitude," in Mem. 1736, pp. 443-468. In this memoir, after completing a detailed analysis of the possible errors, Bouguer demonstrates the following: "The result, in consequence, is that the measurement of degrees of longitude is no longer adequate to decide the question that divides Mathematicians today about the shape of the Earth." P. 466.

43. D. de Mairan, "Experiences sur la longueur de pendule à secondes à Paris: avec des Remarques sur cette matière, et sur quelques autres qui s'y rapportent," in Mem. 1735, pp. 153-220, and Hist. 1735, pp. 81-92.

44. A. C. Clairaut, "Examen des différents oscillations qu'un corps suspendu par un fil, peut faire lorsqu'on lui donne una impulsion quelconque," in Mem. 1735, pp. 281-298.

45. Manfredi, "Méthode de vérifier la figure de la Terre par les parallaxes de la Lune," in Mem. 1734, pp. 1-20. The text is on page 1.

46. P. L. M. Maupertuis, "Sur la figure de la terre..." in Mem. 1733, p. 159, Reg. 1733, pp. 116ff.

47. Reg. 1733, Sèance 23 Décembre 1733.

48. P. L. M. Maupertuis, "La figure de la Terre déterminée par messieurs de l'Académie Royale des Sciences, qui ont mesuré le degré du Meridien au Cercle Polaire." Paper read at the solemn public session of the Academy on November 1737 in Mem. 1737, pp. 389-469. The texts are on pages 390 and 391, respectively.

49. Voltaire to Jean Batiste Nicolas Formont; April 17, 1735. The Complete Works of Voltaire, op. cit., D 864.

50. La Condamine to Voltaire; Porto-Bello, December 15, 1735. The Complete..., op. cit., D 961.

51. Oeuvres Complètes de Voltaire, Vol. X (Paris, 1877), page 511. The poem was published in 1736.

52. Voltaire to Berger; Cirey, January 29, 1736. The Complete..., op. cit., D 998.

53. Pierre Robert le Cornier de Cedeville to Voltaire; February 5, 1736. The Complete..., op. cit. D 1002. For the presentation of these texts in their historical context, a book by V. Bitterli, Los "salvajes" y los "civilizados." El encuentro de Europa y Ultramar (Mexico, 1982), has been very useful. It contains a detailed analysis of the thought of Voltaire and his contemporaries on the colonial question.

54. A. de Ulloa, Relación..., I, pp. 37-38.

55. Mairan to Delisle; Paris, January 14, 1736. ANP, Marine, 2JJ63. See also Hist. 1735, p. 31. On June 15, 1735, Mme. Châtelet wrote to L. F. Armand Du Plessis saying that "At Fontenelle's request, Maupertuis is going to the pole to measure the Earth," in CWV, D 876.

56. See C. J. Nordmann, "L'expedition de Maupertuis et Celsius en Laponie," in Cahiers d'Histoire Mondiale, X-1, 74-97, 1966.

57. Cited by H. Brown, Science and the Human Comedy. Natural Philosophy in French literature from Rabelais to Maupertuis (Toronto and Buffalo, 1976), pp. 174-175.

58. Souciet, S.J. to Delisle; Paris, May 16, 1738. Arch. Nat., Marine, 2JJ64, pièce 122.

59. Celsius to Delisle; Tornea, November 20, 1736, Arch. Nat., Marine, 2JJ64, pièce 2. The description of the voyage and the difficulties can be found in detail in the work of Outhier, one of the members of the expedition: Journal d'un voyage au Nord fait en 1736 et 1737 (Paris, 1744).

60. P. L. M. Maupertuis,, "Relation du voyage fait par ardre du Roi au cercle polaire, pour déterminer la figure de la Terre," in Oeuvres, III, pp. 71-175. The text is on p. 158.

61. Ibidem, p. 161.

62. Ibidem, p. 166-168.

63. Maupertuis, "Lettre sur..." op. cit., p. 264.

64. Voltaire to Maupertuis; Fontainebleau, 3.XI.1732, in CWV, D 534.

65. Voltaire to Maupertuis; Montjeu, 29.IV.1734, in CWV, D 728. A few months before (Paris, 14.IX.33 CWV D 653), foreseeing the events, he wrote to Jean Jacob Vernet as follows: "The English letters you speak of are written with that spirit of liberty that perhaps will earn me persecution in France, but that will win me France's respect; they will only appear in English, and I have done everything possible to stop the French edition. I do not know if I will succeed, but you judge the difference that exists between the English and the French; these letters have been philosophical only to the readers in London, and in Paris they are already calling them impious without even having them available. Anyone who is tolerant here is soon called an atheist..."

66. Voltaire-La Condamine; 22.VI.1734, in CWV, D 759.

67. L. Anglivel de la Beaumelle, Vie de Maupertuis par...suivi de lettres enédites de Frederic Le Grand et de Maupertuis (Paris, 1856), p. 33.

68. Voltaire, Cartas filosóficas, op. cit., p. 117-118.

69. Mme. Châtelet to F. Algarotti; Cirey, 10.I.1738 in CWV, D 1421.

70. Mme. Châtelet to Maupertuis; Cirey, 10.I.1738 in CWV, D 1422.

71. The fruit of this haste were several errors that would later be corrected in the editions of 1741 and 1745. On this work of Voltaire see the study by M. S. Staum, "Newton and Voltaire: Constructive Skeptics," in Studies on Voltaire and the Eighteenth Century, 62, 29-56, 1968.

72. The stanzas mentioned were printed in the Anecdotes Physiques et Morales (no place, no date), a work attributed to Maupertuis. As president of the Berlin Academy, he had a bitter argument with his former protegé Köning. We will not go into a description of this occurrence, memorable due to the fact that Voltaire, having taken sides against the President, published numerous pamphlets in which he carried on a fierce critique. To mention the titles of only a few of these will be enough to convey an idea of the perseverance with which Voltaire assaulted his "chef de secte": Micromegas, Doctteur Akakia, médecin du pape, La Querelle, La seance memorable, Extrait d'une lettre d'un académicien de Berlin, Art de bien argumenter, Lettre au Secrétaire éternel, La berlue, and so forth. One may find more information in the articles on Maupertuis in Biographie Universelle (Michaud) Ancienne et Moderne and in the Nouvelle Biographie Générale. In Micromegas, perhaps the most famous of the stories relating to the topic and inspired by Swift's Gulliver's Travels, Voltaire offered a ridiculous view of the men and the work done on the expedition to Lapland. The plot of the story

was as follows. Two extraterrestrials, one from Sirius and the other from Saturn, travel through space with no fixed destination until they reach the planet Earth on July 5, 1737, in the Baltic Sea. They were so gigantic that they could walk around the Earth in 36 hours. The inhabitant of Sirius, named Micromegas, took a microscope and observing with close attention he discerned the existence of a little thing the size of a whale floating in the Baltic. Through other information supplied by Voltaire the reader can easily guess that it is the boat in which the expeditionaries to the north were returning to France. Picking up the boat with exquisite care and placing it under his microscope, he could see with enormous satisfaction that some tiny machines were moving and talking anxiously. Voltaire writes, making reference to the supposed amorous escapades of Maupertuis, that the men, frightened, took "...their quadrants, their sectors, two Lapp girls...." Wanting to establish contact with these miserable creatures, the giants were surprised when the one who seemed most disposed to it (Maupertuis), after making a few movements, told them proudly that he had calculated that they were 1000 fathoms tall. The giant from Saturn, surprised by the accuracy of the figure, exclaimed: "I see now more than ever that one must not judge things by their apparent size. Oh God, you gave intelligence to bits of substance that seem so negligible!...." After that, the extraterrestrials, interested in these minuscule beings, asked them some questions; Voltaire used the story to illustrate the petulant and arrogant ignorance of the men. The edition we have used is extremely rare; however, since the story is very short there should be no difficulty in locating the quotations.

73. E. M. de Montigny to Voltaire; Paris, February 4, 1738, in CWV, D 1443.

74. Voltaire to Maupertuis; January 1738 in CWV, D 1423.

75. Maupertuis to Celsius; St. Etien, 8.VI.1738 in A.A.S., Dossier Maupertuis.

76. Maupertuis, Figure de la terre determinée par les observations de MM. Maupertuis, Clairaut, Camus, Le Monnier et Outhier (Paris, 1738).

77. All these works, although anonymous, were rightly attributed to Maupertuis by J. F. Lalande, Bibliographie astronomique, op. cit., p. 407. Since then (1803), no one has cast doubt on his authority.

78. Maupertuis to Celsius; Paris, 31.I.1738. A.A.S. Dossier Maupertuis.

79. A. Celsius, De observationibus pro figura telluris determinanda in Gallia habitis, Disquisitio. Autore Andre Celsio, In Acad. Upsal. Astron. Prof. Regio, Christ. Franc. Regis Pensionario, Soc. Reg. Lit. & Scient. Svec. Secretario, Societatum Regg. Codn. & Berol. atque Academiarum Nat. Curios. & Inst. Scient. Bonon. Membro. Upsaliae, Typis Höjerianis (1738). This rare booklet of 20 pp., together with others by the same author, can be found among the papers of Delisle of AOP, ms. C-2-7. We think it in the interest of history of science to supply at least their titles: Eff Bref lill N.N. Dm Ttordens Figur...And. Celsius... 1736 and Epistola de Figura Terrae. Andrea Celsius...1736 (probably a translation of the previous). There is also another manuscript memoir on the theme of the shape of the Earth which bears the title: De figura terrae. Auctore G.W. Kraff, read at the Uppsala Academy between June and August of 1737.

80. Cassini, Reponse à la dissertation de M. Celsius, Professeur Royal d'Astronomie à Upsal, sur les observations que l'on a faites en France pour déterminer le Figure de la Terre (Paris, 1738).

81. Celsius to Delisle; Uppsala, August 16, 1738. Arch. Nat., Marine, 2JJ64, pièce 118.

82. Memoires des Trevoux, 38, pp. 1890-1, 1738.

83. Hist. 1740, p. 74.

84. Cassini de Thury, La Meridienne de l'Observatoire Royal de Paris, vérifiée dans toute l'étendue du Royaume par des nouvelles observations (Paris, 1744).

85. Voltaire to Maupertuis, CWV, D 2153.

86. Taken from the catalogue of the expedition made in 1979 at the National Library in Paris to commemorate the "250th anniversary of the birth of Bougainville," under the title: A la découverte de la Terre. Dix siècles de cartographie (Paris, 1979), p. 80.