Dialogue Concerning the Two Chief World Systems

by Galileo Galilei (1632)

Cover Page

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The open-minded and lettered Sagredo in Galileo's dialogue was a close friend of the scientist. Salviati represents the views of Galileo himself. Simplicio, the philosopher, is a fictitious straw man.

Links: *Second Day* *Third Day* *Fourth Day*

TO THE DISCERNING READER

Several years ago there was published in Rome a salutary edict which, in order to obviaie the dangerous tendencies of our present age, imposed a seasonable silence upon the Pythagorean opinion that the earth moves There were those who impudently asserted that this decree had its origin not injudicious inquire, but in passion none too well informed Complaints were to be heard that advisers who were totally unskilled at astronomical observations ought not to clip the wings of reflective intellects by means of rash prohibitions.

Upon hearing such carping insolence, my eal could not be contained Being thoroughly informed about that prudent determination, I decided to appear openly in the theater of the world as a witness of the sober truth. I was at that time in Rome; I was not only received by the most eminent prelates of that Court, but had their applause; indeed this decree was not published without some previous notice of it having been given to me. Therefore I propose in the present work to show to foreign nations that as much is understood

of this matter in Italy, and pariicularly in Rome, as transalpine diligence can ever have imagined Collecting all the reflections thai properly concern the Copernican system, I shall make it known that everything was brought before the attention of the Roman censorship, and that there proceed from this clime not only dogmas for the welfare of the soul, but ingenious discoveries for the delight of the mind as well.

To this end I have taken the Copernican side in the disco urse, proceeding as with a pure mathematical hypothesis and striving by every artipee to represent it as superior to supposing the earth motionless–not, indeed absolutely, but as against the arguments of some professed Peripatetics. These men indeed deserve not even that name, for they do not walk about; they are content to adore the shadows, philosophizing not with due circumspection but merely from having memorized a fow ill-understood principles.

Three principal headings are treated First, I shall try to show that all experiments practicable upon the earth are inszyfficient measures for proving its mobility, since they are indiferently adaptable to an earth in motion or at rest. I hope in so doing to reveal many observations unknown to the ancients. Secondly, the celestial phenomena will be examined strengthening the Copernican hypothesis until it might seem that this must triumph absolutely. Here new reflections are adjoined which might be used in order to simplfy astronomy, though not because of any necess ire importeded by nature. In the third place, I shall propose an ingenious speculation. It happens that long ago I said that the unsolved problem of the ocean tides might receive some light from assuming the motion of the earth. This assertion of mine, passing by word of mouth, found loving fathers who adopted it as a child of their own ingenuity. Now, so that no stranger may ever a who, arming himself with our weapons, shall charge us with want of attention to such an important matter, I have thought it good to reveal those probabilities which might render this plausible, given that the earth moves.

I hope that from these considerations the world will come to know that if other nations have navigated more, we have not theorized less. It is not from failing to take count of what others have thought that we have yielded to asserting that the earth is motionless, and holding the contrary to be a mere mathematical caprice, but (if for nothing else) for those reasons that are supplied by piety, religion, the knowledge of Divine Omnipotence, and a consciousness of the limitations of the human mind I have thought it most appropriate to explain these concepts in the form of dialogues, which, no! being restricted to the rigorous observance of mathematical laws, make room also for digressions which are sometimes no less interesting than the principal argument.

Many years ago I was often to be found in the marvelous city of Venice, in discussions with Signore Giovanni Francesco Sagredo, a man of noble extraction and trenchant wit. Prom Florence came Signore Filippo Salviati, the least of whose glories were the eminence of his blood and the magnfficence of his fortune. His was a sublime intellect which fed no more hungrily upon any pleasure than it did upon fine meditations. I often talked with these two of such matters in the presence of a certain Peripatetic philosopher whose greatest obstacle in apprehending the truth seemed to be the reputation he had acquired by his interpretations of Aristotle.

Now, since bitter death has deprived Venice and Florence of those two great luminaries in the very meridian of their years, I have resolved to make their fame live on in these pages, so far as my poor abilities will permit, by introducing them as interlocutors in the present argument. (Nor shall the good Peripatetic lack a place; because of his excessive affection toward the Commentaries of Simplicius,I have thought fit to leave him under the name of the author he so much revered, without mentioning his own) May it please those two great souls, ever venerable to my heart, to accept this public monument of my undying love. And may the memory of their eloquence assist me in delivering to posterity the promised reflections.

It happened that several discussions had taken place casually at various times among these gentlemen, and had rather whetted than satisfied their thirst for learning. Hence very wisely they resolved to meet together on certain days during which, setting aside all other business, they might apply themselves more methodically to the contemplation ofthe wonders of God in the heavens and upon the earth. They met in the palace of the illustrious Sagredo; and, after the customary but brief exchange of compliments, Saiviati commenced as follows.

THE FIRST DAY

INTERLOCUTORS

SALVIATI, SAGRFDO, AND SIIMPLICIO

SALVIATI. Yesterday we resolved to meet today and discuss as clearly and in as much detail as possible the character and the efficacy of those laws of nature which up to the present have been put forth by the partisans of the Aristotelian and Ptolemaic position on the one hand, and by the followers of the Copemican system on the other. Since Copernicus places the earth among the movable heavenly bodies, making it a globe like a planet, we may well begin our discussion by examining the Peripatetic steps in arguing the impossibility of that hypothesis; what they are, and how great is their force and effect. For this it is necessary to introduce into nature two substances which differ essentially. These are the celestial and the elemental, the former being invariant and eternalo the latter, temporary and destructible. This argument Aristotle treats in his book *De Caelo*, introducing it with some discourses dependent upon certain general assumptions, and afterwards confirming it by experiments and specific demonstrations. Following the same method, I shall first propound, and then freely speak my opinion, submitting myself to your criticisms -- particularly those of Simplicio, that stout champion and defender of Aristotelian doctrines.

The first step in the Peripatetic arguments is Aristotle's proof of the completeness and perfection of the world. For, he tells us, it is not a mere line, nor a bare surface, but a body having length, breadth, and depth. Since there are only these three dimensions, the world, having these, has them all, and, having the Whole, is perfect. To be sure, I much wish that Aristotle had proved to me by rigorous deductions that simple length constitutes the dimension which we call a line, which by the addition of breadth becomes a surface; that by further adding altitude or depth to this there results a body, and that after these three dimensions there is no passing farther‹so that by these three alone, completeness, or, so to speak, wholeness is concluded. Especially since he might have done so very plainly and speedily.

SIMP. What about the elegant demonstrations in the second, third, and fourth texts, after the definition of "continuous"? Is it not there first proved that there are no more than three dimensions, since Three is everything, and everywhere? And is this not confirmed by the doctrine and authority of the Pythagoreans, who say that all things are determined by three -- beginning, middle, and end -- which is the number of the Whole? Also, why leave out another of his reasons; namely, that this number is used, as if by a law of nature, in sacrifices to the gods? Furthermore, is it not dictated by nature that we attribute the title of "all" to those things that are three, and not less? For two are called "both," and one does not say "all" unless there are three.

You have all this doctrine in the second text. Afterwards, in the third we read, for greater knowledgethat All, and Whole, and Perfect are formally one and the same; and that therefore among figures only the solid is

complete. For it alone is determined by three, which is All; and, being divisible in three ways, it is divisible in every possible way. Of the other figures, one is divisible in one way, and the other in two, because they have their divisibility and their continuity according to the number of dimensions allotted to them. Thus one figure is continuous in one way, the other in two; but the third, namely the solid, is so in every way.

Moreover, in the fourth text, after some other doctrines, does he not clinch the matter with another proof? To wit: a transition is made only according to some defect; thus there is a transition in passing from the line to the surface, because the line is lacking in breadth. But it is impossible for the perfect to lack anything, being complete in every way; therefore there is no transition beyond the solid or body to any other figure.

Do you not think that in all these places he has sufficiently proved that there is no passing beyond the three dimensions, length, breadth, and thickness; and that therefore the body, or solid, which has them all, is perfect?

SALV. To tell you the truth, I do not feel impelled by all these reasons to grant any more than this: that whatever has a beginning, middle, and end may and ought to be called perfect. I feel no compulsion to grant that the number three is a perfect number, nor that it has a faculty of conferring perfection upon its possessors. I do not even understand, let alone believe, that with respect to legs, for example, the number three is more perfect than four or two; neither do I conceive the number four to be any imperfection in the elements, nor that they would be more perfect if they were three. Therefore it would have been better for him to leave these subtleties to the rhetoricians, and to prove his point by rigorous demonstrations such as are suitable to make in the demonstrative sciences.

SIMP. It seems that you ridicule these reasons, and yet all of them are doctrines to the Pythagoreans, who attribute so much to numbers. You, who are a mathematician, and who believe many Pythagorean philosophical opinions, now seem to scorn their mysteries.

SALV. That the Pythagoreans held the science of the human understanding and believed it to partake of divinity simply because it understood the nature of numbers, I know very well; nor am I far from being of the same opinion. But that these mysteries which caused Pythagoras and his sect to have such veneration for the science of numbers are the follies that abound in the sayings and Writings of the vulgar, I do not believe at all. Rather I know that, in order to prevent the things they admired from being exposed to the slander and scorn of the common people, the Pythagoreans condemned as sacrilegious the publication of the most hidden properties of numbers or of the incommensurable and irrational quantities which they investigated. They taught that anyone who had revealed them was tormented in the other world. Therefore I believe that some one of them, just to satisfy the common sort and free himself from their inquisitiveness, gave it out that the mysteries of numbers were those trifles which later spread among the vulgar. Such astuteness and prudence remind one of the wise young man who, in order to stop the importunity of his mother or his inquisitive wife -- I forget which -- who pressed him to impart the secrets of the Senate, made up some story which afterwards caused her and many other women to be the laughing-stock of that same Senate.

SIMP. I do not want to join the number of those who are too curious about the Pythagorean mysteries. But as to the point in hand, I reply that the reasons produced by Aristotle to prove that there are not and cannot be more than three dimensions seem to me conclusive; and I believe that if a more cogent demonstration had existed, Aristotle would not have omitted it.

SAGR. You might at least add, "if he had known it or if it had occurred to him." Salviati, you would be doing me a great favor by giving me some effective arguments. if there are any clear enough to be comprehended by me.

SALV. Not only by you, but by Simplicio too; and not merely comprehended, but already known -- though

perhaps without your realizing it. And to make them easier to understand, let us take this paper and pen which I see already prepared for such occasions, and draw a few figures.

First we shall mark these two points, A and B, and draw from one to the other the curved lines ACB and ADE, and the straight line P3. (Fig. 1) I ask which of them is to your mind the one that determines the distance between the ends A and B, and why?

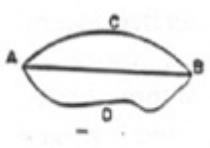

Figure 1

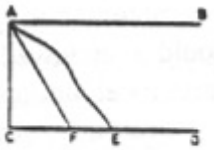

Figure 2

SAGR. I should say the straight line, and not the curves, because the straight one is shorter and because it is unique, distinct, and determinate; the infinite others are indefinite, unequal, and longer. It seems to me that the choice ought to depend upon that which is unique and definite.

SALV. We have the straight line, then, as determining the distance between the two points. We now add another straight line parallel to AB -- let it be CD -- so that between them there lies a surface of which I want you to show the breadth. (Fig. 2) Therefore starting from point A, tell me how and which way you will go, stopping on the line CD, so as to show me the breadth included between those lines. Would you determine it according to the measure of the curve AF, or the straight line AF, or. . . ?

SIMP. According to the straight line AF, and not according to the curve, such being already excluded for such a use.

SAGR. But I should take neither of them, seeing that the straight line AF runs obliquely. I should draw a line perpendicular to CD, for this would seem to me to be the shortest, as well as being unique among the infinite number of longer and unequal ones which may be drawn from the point A to every other point of the opposite line CD.

SALV. Your choice and the reason you adduce for it seem to me most excellent. So now we have it that the first dimension is determined by a straight line; the second (namely, breadth) by another straight line, and not only straight, but at right angles to that which determines the length. Thus we have defined the two dimensions of a surface; that is, length and breadth.

But suppose you had to determine a height -- for example, how high this platform is from the pavement down below there. Seeing that from any point in the platform we may draw infinite lines, curved or straight, and all of different lengths, to the infinite points of the pavement below, which of all these lines would you make use of?

SAGR. I would fasten a string to the platform and, by hanging a plummet from it, would let it freely stretch till it reached very near to the pavement; the length of such a string being the straightest and shortest of all the lines that could possibly be drawn from the same point to the pavement, I should say that it was the true height inthis case.

SALV. Very good. And if, from the point on the pavement indicated by this hanging string (taking the pavement to be level and not inclined), you should produce two other straight lines, one for the length and the other for the breadth of the surface of the pavement, what angles would they make with the thread?

SAGR. They would surely meet at right angles, since the string faIls perpendicularly and the pavement is quite flat and level.

SALV Therefore if you assign any point for the point of origin of your measurements, and from that produce

a straight line as the determinant of the first measurement (that is, of the length) it will necessarily follow that the one which is to define the breadth leaves the first at a right angle. That which is to denote the altitude, which is the third dimen sion, going out from the same point, also forms right angles and not oblique angles with the other two. And thus by three perpendiculars you will have determined the three dimensions AB length, AC
breadth, and AD height, by three unique, definite, and shortest lines. (Fig. 3) And since clearly no more lines can meet in the said point to make right angles with them, and the dimensions must be determined by the only straight lines which make right angles with each other, then the dimensions are no more than three; and whatever has the three has all of them, and that which has all of them is divisible in every way, and that which is so, is perfect, etc.

SIMP. Who says that I cannot draw other lines? Why may I not bring another line from beneath to the point A, which will be perpendicular to the rest?

SALV. Surely you cannot make more than three straight lines meet in the same point and form right angles with each other!

SAGR. Yes, because it seems to me that what Simphcio means would be the same DA prolonged downward. In that way there might also be drawn two others; but they would be the same as the first three, differing only in that whereas now they merely touch, they would then intersect. But this would not produce any new dimensions.

SIMP. I shall not say that this argument of yours cannot be conclusive. But I still say, with Aristotle, that in physical matters one need not always require a mathematical demonstration.

SAGR. Granted, where none is to be had; but when there is one at hand, why do you not wish to use it? But it would be good to spend no more words on this point, for I think that Salviati will have conceded both to Aristotle and to you, without further demonstration, that the world is a body, and perfect; yea, most perfect, being the chief work of God.

SALV. Exactly so. Therefore leaving the general contemplation of the whole, let us get to the consideration of the pans. Aristotle in his first division separates the whole into two differing and, in a way, contrary parts: namely, the celestial and the elemental, the former being ingenerable, incorruptible, inalterable, impenetra ble, etc.; the latter being exposed to continual alteration, mutation, etc. He takes this difference from the diversity of local motions as his original principle. With this step he proceeds.

Leaving, so to speak, the sensible world and retiring into the ideal world, he begins architec tonically to consider that, nature being the principle of motion, it is appropriate that natural bodies should be endowed with local motion. He then declares local motions to be of three kinds: namely, circular, straight, and mixed straight-and-circular. The first two he calls simple, because of all lines only the circular and the straight are simple. Hereupon, restricting himself somewhat, he newly defines among the simple motions one, the circular, to be that which is made around the center; and the other, the straight, to be upward and downward -- upward, that which goes from the center; and downward, whatever goes toward the center. And from this he infers it to be necessary and proper that all simple motions are confined to these three kinds; namely, toward the center, away from the center, and around the center. This answers, he says, with a certain beautiful harmony to what has been said previously about the body; it is perfect in three things, and its motion is likewise.
These motions being established, he goes on to say that some natural bodies being simple, and others composites of those (and he calls those bodies simple which have a natural principle of motion, such as fire and earth), it is proper that simple motions should be those of simple bodies, and that mixed motions should belong to compound bodies; in such a way, moreover, that compounds take the motion of that part which

predominates in their composition.

SAGR. Wait awhile, Salviati, for in this argument I find so many doubts assailing me on all sides that I shall either have to tell them to you if I want to pay attention to what you are going to say, or withhold my attention in order to remember my doubts.

SALV. I shall willingly pause, for I run the same risk too, and am on the verge of getting shipwrecked. At present I sail between rocks and boisterous waves that are making me lose my bearings, as they say. Therefore, before I multiply your difficulties, propound them.

[Discussion of earth's place in the solar system:]

SALV. I see we are once more going to engulf ourselves in a boundless sea from which there is no getting out, ever. This is navigating without compass, stars, oars, or rudder, in which we must needs either pass from bank to bank or run aground, or sail forever lost. If, as you suggested, we are to get on with our main subject, it is necessary for the present to put aside the general question whether straight motion is necessary in nature and is proper to some bodies, and proceed to demonstrations, observations, and particular experiments. First we must propound all those that have been put forward to prove the earth's stability by Aristotle, Ptolemy, and others, trying next to resolve them. Finally we must produce those by which a person may become persuaded that the earth, no less than the moon or any other planet, is to be numbered among the natural bodies that move circularly.

SAGR. I submit to the latter more willingly, as I am better satisfied with your architectonic and general discourse than with that of Aristotle. For yours satisfies me without the least misgiving, while the other blocks me in some way at every turn. Nor do I know why Simplicio should not be quickly satisfied with the argument you put forward to prove that motion in a straight line can have no place in nature, so long as we suppose the parts of the universe to be disposed in the best arrangement and perfectly ordered.

SALV. Stop there, Sagredo. for now a way occurs to me in which Simplicio may be given satisfaction, provided only that he does not wish to stay so closely tied to every phrase of Aristotle's as to hold it sacrilege to depart from a single one of them.

There is no doubt that to maintain the optimum placement and perfect order of the parts of the universe as to local situation, nothing will do but circular motion or rest. As to motion by a straight line, I do not see how it can be of use for anything except to restore to their natural location such integral bodies as have been accidentally removed and separated from their whole, as we have just said.

Let us now consider the whole terrestrial globe, and let us see what can happen to make it and the other world bodies keep themselves in the natural and best disposition. One must either say that it is at rest and remains perpetually immovable in its place, or else that it stays always in its place but revolves itself, or finally that it goes about a center, moving along the circumference of a circle. Of these events, Aristotle and Ptolemy and all their followers say that it is the first which has always been observed and which will be forever maintained; that is, perpetual rest in the same place. Now why, then, should they not have said from the start that its natural property is to remain motionless, rather than making its natural motion downward, a motion with which it never did and never will move? And as to motion by a straight line, let it be granted to us that nature makes use of this to restore particles of earth, water, air, fire, and every other integral mundane body to their whole, when any of them find themselves separated and transported into some improper place unless this restoration can also be made by finding some more appropriate circular motion. It seems to me that this original position fits all the consequences much better, even by Aristotle's own method, than to attribute straight motion as an intrinsic and natural principle of the elements. This is obvious; for let me ask the Peripatetic if, being of the opinion that celestial bodies are incorruptible and eternal, he believes

that the terrestrial globe is not so, but corruptible and mortal, so that there will come a time when, the sun and moon and other stars continuing their existence and their operations, the earth will not be found in the universe but will be annihilated along with the rest of the elements, and I am certain that he would answer, No. Therefore generation and corruption belong to the parts and not to the whole; indeed, to very small and superficial parts which are insensible in comparison to the whole mass. Now since Aristotle argues generation and corruption from the contrariety of straight motions, let us grant such motions to the parts, which alone change and decay. But to the whole globe and sphere of the elements will be ascribed either circular motion or perpetual continuance in its proper place -- the only tendencies fined for the perpetuation and maintenance of perfect order.

What is thus said of earth may be said as reasonably of fire and of the greater part of the air, to which elements the Peripatetics are forced to assign as an intrinsic and natural motion one with which they were never moved and never will be, and to abolish from nature that motion with which they move, have moved, and are to be moved perpetually. I say this because they assign an upward motion to air and fire, which is a motion that never belongs to the said elements, but only to some of their parti cles -- and even then only to restore them to perfect arrangement when they are out of their natural places. On the other hand, they call circular motion (with which they are incessantly moved) preternatural to them, forgetting what Aristotle has said many times, that nothing violent can last very long.

SIMP. To all these things we have the most suitable answers, which I omit for the present in order that we may come to the particular reasons and sensible experiments which ought to be finally preferred, as Aristotle well says, above anything that can be supplied by human argument.

SAGR. Then what has been said up to now will serve to place under consideration which of two general arguments has the more probability. First there is that of Aristotle, who would persuade us that sublunar bodies are by nature generable and corruptible, etc., and are therefore very different in essence from celestial bodies, these being invariant, ingenerable, incorruptible, etc. This argument is deduced from differences of simple motions. Second is that of Salviati, who assumes the integral parts of the world to be disposed in the best order, and as a necessary consequence excludes straight motions for simple natural bodies as being of no use in nature; he takes the earth to be another of the celestial bodies, endowed with all the prerogatives that belong to them. The latter reasoning suits me better up to this point than the other. Therefore let Simplicio be good enough to produce all the specific arguments, experiments, and observations, both physical and astronomical, by which one may be fully persuaded that the earth differs from the celestial bodies, is immovable, and is located in the center of the universe, or anything else that would exclude the earth from being movable like a planet such as Jupiter, or the moon, etc. And you, Salviati, have the kindness to reply step by step.

SIMP. For a beginning, then, here are two powerful demonstrations proving the earth to be very different from celestial bodies. First, bodies that are generable corruptible, alterable, etc., are quite different from those that are ingenerable, incorruptible, inalterable, etc. The earth is generable, corruptible, alterable, etc., while celestial bodies are ingenerable, incorruptible, inalterable, etc. Therefore the earth is very different from the celestial bodies.

SAGR. With your first argument, you bring back to the table what has been standing there all day and has just now been carried away.

SIMIP. Softly, sir; hear the rest, and you will see how different it is from that. Formerly the minor premise was proved *a priori*, and now I wish to prove it *a posteriori*. See for yourself whether this is the same thing. I shall prove the minor, because the major is obvious.

Sensible experience shows that on earth there are continual generations, corruptions, alter-ations, etc., the

like of which neither our senses nor the traditions or memories of our ancestors have ever detected in heaven; hence heaven is inalterable, etc., and the earth alterable, etc., and therefore different from the heavens.

The second argument I take from a principal and essential property, which is this: whatever body is naturally dark and devoid of light is different from luminous and resplendent bodies; the earth is dark and without light, and celestial bodies are splendid and full of light; therefore, etc. Answer these, so that too great a pile does not accumulate, and then I will add others.

SALV. As to the first, for whose force you appeal to experience, I wish you would tell me precisely what these alterations are that you see on the earth and not in the heavens, and on account of which you call the earth alterable and the heavens not.

SIMP. On earth I continually see herbs, plants, animals generating and decaying; winds, rains, tempests, storms arising; in a word, the appearance of the earth undergoing perpetual change. None of these changes are to be discerned in celestial bodies, whose positions and configurations correspond exactly with everything men remember, without the generation of anything new there or the corruption of anything old.

SALV. But if you have to content yourself with these visible, or rather these seen experiences, you must consider China and America celestial bodies, since you surely have never seen in them these alterations which you see in Italy. Therefore, in your sense, they must be inalterable.

SIMP. Even if I have never seen such alterations in those places with my own senses, there are reliable accounts of them; besides which, *cum eadem sit ratio totius et partium*, those counties being a pan of the earth like ours, they must be alterable like this.

SALV. But why have you not observed this, instead of reducing yourself to having to believe the tales of others? Why not see it with your own eyes?

SIMP. Because those countries are far from being exposed to view; they are so distant that our sight could not discover such alterations in them.

SALV. Now see for yourself how you have inadvertently revealed the fallacy of your argument. You say that alterations which may be seen near at hand on earth cannot be seen in America because of the great distance. Well, so much the less could they be seen in the moon, which is many hundreds of times more distant. And if you believe in alterations in Mexico on the basis of news from there, what reports do you have from the moon to convince you that there are no alterations there? From your not seeing alterations in heaven (where if any occurred you would not be able to see them by reason of the distance, and from whence no news is to be had), you cannot deduce that there are none, in the same way as from seeing and recognizing them on earth you correctly deduce that they do exist here.

SIMIP. Among the changes that have taken place on earth I can find some so great that if they had occurred on the moon they could yen well have been observed here below. From the oldest records we have it that formerly, at the Straits of Gibraltar, Abila and Calpe were joined together with some lesser mountains which held the ocean in check; but these mountains being separated by some cause, the opening admitted the sea, which flooded in so as to form the Mediterranean. When we consider the immensity of this, and the difference in appearance which must have been made in the water and land seen from afar, there is no doubt that such a change could easily have been seen by anyone then on the moon. Just so would the inhabitants of earth have discovered any such alteration in the moon; yet there is no history of such a thing being seen. Hence there remains no basis for saying that anything in the heavenly bodies is alterable, etc.

SALV. I do not make bold to say that such great changes have taken place in the moon, but neither am I sure that they could not have happened. Such a mutation could be represented to us only by some variation between the lighter and the darker parts of the moon, and I doubt whether we have had observant selenographers on earth who have for any considerable number of years provided us with such exact selenography as would make us reasonably conclude that no such change has come about in the face of the moon. Of the moon's appearance, I find no more exact description than that some say it represents a human face; others, that it is like the muzzle of a lion; still others, that it is Cain with a bundle of thorns on his back. So to say "Heaven is inalterable, because neither in the moon nor in other celestial bodies are such alterations seen as are discovered upon the earth" has no power to prove anything.

SAGR. This first argument of Simplicio's leaves me with another haunting doubt which I should like to have removed. Accordingly I ask him whether the earth was generable and corruptible before the Mediterranean inundation, or whether it began to be so then?

SIMP. It was without doubt generable and corruptible before, as well; but that was so vast a mutation that it might have been observed as far as the moon.

SAGR. Well, now; if the earth was generable and corruptible before that flood, why may not the moon be equally so without any such change? Why is something necessary in the moon which means nothing on the earth?

SALV. A very penetrating remark. But I am afraid that Simplicio is altering the meaning a bit in this text of Aristotle and the other Peripatetics. They say that they hold the heavens to be inalterable because not one star there has ever been seen to be generated or corrupted, such being probably a lesser part of heaven than a city is of the earth; yet innumerable of the latter have been destroyed so that not a trace of them remains.

SAGR. Really, I thought otherwise, believing that Simplicio distorted this exposition of the text so that he might not burden the Master and his disciples with a notion even more fantastic than the other. What folly it is to say, "The heavens are inalterable because stars are not generated or corrupted in them." Is there perhaps someone who has seen one terrestrial globe decay and another regenerated in its place? Is it not accepted by all philosophers that very few stars in the heavens are smaller than the earth, while a great many are much bigger? So the decay of a star in heaven would be no less momentous than for the whole terrestrial globe to be destroyed! Now if, in order to be able to introduce generation and corruption into the universe with certainty, it is necessary that as vast a body as a star must be corrupted and regenerated, then you had better give up the whole matter; for I assure you that you will never see the terrestrial globe or any other integral body in the universe so corrupted that, after having been seen for many ages past, it dissolves without leaving a trace behind.

SALV. But to give Simplicio more than satisfaction, and to reclaim him if possible from his error, I declare that we do have in our age new events and observations such that if Aristotle were now alive, I have no doubt he would change his opinion. This is easily inferred from his own manner of philosophizing, for when he writes of considering the heavens inalterable, etc., because no new thing is seen to be generated there or any old one dissolved, he seems implicitly to let us understand that if he had seen any such event he would have reversed his opinion, and properly preferred the sensible experience to natural reason. Unless he had taken the senses into account, he would not have argued immutability from sensible mutations not being seen.

SIMP. Aristotle first laid the basis of his argument *a priori*, showing the necessity of the inalterability of heaven by means of natural, evident, and clear principles. He afterward supported the same *a posteriori*, by the senses and by the traditions of the ancients.

SALV. What you refer to is the method he uses in writing his doctrine, but I do not believe it to be that with which he investigated it. Rather, I think it certain that he first obtained it by means of the senses, experiments, and observations, to assure himself as much as possible of his conclusions. Afterward he sought means to make them demonstrable. That is what is done for the most part in the demonstrative sciences; this comes about because when the conclusion is true, one may by making use of analytical methods hit upon some proposition which is already demonstrated, or arrive at some axiomatic principle; but if the conclusion is false, one can go on forever without ever finding any known truth -- if indeed one does not encounter some impossibility or manifest absurdity. And you may be sure that Pythagoras, long before he discovered the proof for which he sacrificed a hecatomb, was sure that the square on the side opposite the right angle in a right triangle was equal to the squares on the other two sides. The certainty of a conclusion assists not a little in the discovery of its proof -- meaning always in the demonstrative sciences. But however Aristotle may have proceeded, whether the reason a priori came before the sense perception *a posteriori* or the other way round, it is enough that Aristotle, as he said many times, preferred sensible experience to any argument. Besides, the strength of the arguments *a priori* has already been examined.

Now, getting back to the subject, I say that things which are being and have been discovered in the heavens in our own time are such that they can give entire satisfaction to all philosophers, because just such events as we have been calling generations and corruptions have been seen and are being seen in particular bodies and in the whole expanse of heaven. Excellent astronomers have observed many comets generated and dissipated in places above the lunar orbit, besides the two new stars of 1572 and 1604, which were indisputably beyond all the planets. And on the face of the sun itself, with the aid of the telescope, they have seen produced and dissolved dense and dark matter, appearing much like the clouds upon the earth: and many of these are so vast as to exceed not only the Mediterranean Sea, but all of Africa, with Asia thrown in. Now, if Aristotle had seen these things, what do you think he would have said and done, Simplicio?

SIMP. I do not know what would have been done or said by Aristotle, who was the master of all science, but I know to some extent what his followers do and say, and what they ought to do and say in order not to remain without a guide, a leader, and a chief in philosophy.

As to the comets, have not these modem astronomers who wanted to make them celestial been vanquished by the *Anti-Tycho*?Vanquished, moreover, by their own weapons; that is, by means of parallaxes and of calculations turned about every which way, and finally concluding in favor of Aristotle that they are all elemental. A thing so fundamental to the innovators having been destroyed, what more remains to keep them on their feet?

SALV. Calm yourself, Simplicio. What does this modem author of yours say about the new stars of 1572 and 1604, and of the solar spots? As far as the comets are concerned I, for my part, care little whether they are generated below or above the moon, nor have I ever set much store by Tycho's verbosity. Neither do I feel any reluctance to believe that their matter is elemental, and that they may rise as they please without encountering any obstacle from the impenetrability of the Peripatetic heavens, which I hold to be far more tenuous, yielding, and subtle than our air. And as to the calculation of parallaxes, in the first place I doubt whether comets are subject to parallax; besides, the inconstancy of the observations upon which they have been computed renders me equally suspicious of both his opinions and his adversary's -- the more so because it seems to me that the *Anti-Tycho* sometimes trims to its author's taste those observations which do not suit his purposes, or else declares them to be erroneous.

SIMP. With regard to the new stars, the *Anti-Tycho* thoroughly disposes of them in a few words, saying that such recent new stars are not positively known to be heavenly bodies, and that if its adversaries wish to prove any alterations and generations in the latter, they must show us mutations made in stars which have already been described for a long time and which are celestial objects beyond doubt. And this can never

possibly be done.

As to that material which some say is generated and dissolved on the face of the sun, no mention is made of it at all, from which I should gather that the author takes it for a fable, or for an illusion of the telescope, (note: The telescope was an object of suspicion in many circles.) or at best for some phenomenon produced by the air; in a word, for anything but celestial matter.

SALV. But you, Simplicio, what have you thought of to reply to the opposition of these importunate spots which have come to disturb the heavens, and worse still, the Peripatetic philosophy? It must be that you, as its intrepid defender, have found a reply and a solution which you should not deprive us of.

SIMP. I have heard different opinions on this matter. Some say, "They are stars which, like Venus and Mercury, go about the sun in their proper orbits, and in passing under it present themselves to us as dark; and because there are many of them, they frequently happen to collect together, and then again to separate." Others believe them to be figments of the air; still others, illusions of the lenses; and still others, other things. But I am most inclined to believe -- yes, I think it certain -- that they are a collection of various different opaque objects, coming together almost accidentally; and therefore we often see that in one spot there can be counted ten or more such tiny bodies of irregular shape that look like snowflakes, or tufts of wool, or flying moths. They change places with each other, now separating and now congregating, but mostly right under the sun, about which, as their center, they move. But it is not therefore necessary to say that they are generated or decay. Rather, they are sometimes hidden behind the body of the sun; at other times, though far from it, they cannot be seen because of their proximity to its immeasurable light. For in the suns eccentric spherethere is established a sort of onion composed of various folds, one within another, each being studded with certain little spots, and moving; and although their movements seem at first to be inconstant and irregular. nonetheless it is said to be ultimately observed that after a certain time the same spots are sure to return. This seems to me to be the most appropriate expedient that has so far been found to account for such phenomena, and at the same time to maintain the incorruptibility and ingenerability of the heavens. And if this is not enough, there are more brilliant intellects who will find better answers.

SALV. If what we are discussing were a point of law or of the humanities, in which neither true nor false exists, one might trust in subtlety of mind and readiness of tongue and in the greater experience of the writers, and expect him who excelled in those things to make his reasoning most plausible, and one might judge it to be the best. But in the natural sciences, whose conclusions are true and necessary and have nothing to do with human will, one must take care not to place oneself in the defense of error; for here a thousand Demostheneses and a thousand Aristotles would be left in the lurch by every mediocre wit who happened to hit upon the truth for himself Therefore, Simplicio, give up this idea and this hope of yours that there may be men so much more leaned, erudite, and well-read than the rest of us as to he able to make that which is false become true in defiance of nature. And since among all opinions that have thus far been produced regarding the essence of sunspots, this one you have just explained appears to you to be the correct one, it follows that all the rest are false. Now to free you also from that one -- which is an utterly delusive chimera -- I shall, disregarding the many improbabilities in it, convey to you but two observed facts against it.

One is that many of these spots are seen to originate in the middle of the solar disc, and likewise many dissolve and vanish far from the edge of the sun, a necessary argument that they must be generated and dissolved. For without generation and corruption, they could appear there only by way of local motion, and they all ought to enter and leave by the very edge.

The other observation, for those not in the rankest ignorance of perspective, is that from the changes of shape observed in the spots, and from their apparent changes in velocity, one must infer that the spots are in contact with the sun's body, and that, touching its surface, they are moved either with it or upon it and in no

sense revolve in circles distant from it. Their motion proves this by appearing to be very slow around the edge of the solar disc, and quite fast toward its center; the shapes of the spots prove the same by appearing very narrow around the sun's edge in comparison with how they look in the vicinity of the center. For around the center they are seen in their majesty and as they really are; but around the edge, because of the curvature of the spherical surface, they show themselves foreshortened. These diminutions of both motion and shape, for anyone who knows how to observe them and calculate diligently, correspond exactly to what ought to appear if the spots are contiguous to the sun, and hopelessly contradict their moving in distant circles, or even at small intervals from the solar body. This has been abundantly demonstrated by our mutual friend in his *Letters to Mark Welser on the Solar Spots*. It may be inferred from the same changes of shape that none of these are stars or other spherical bodies, because of all shapes only the sphere is never seen foreshortened, nor can it appear to be anything but perfectly round. So if any of the individual spots were a round body, as all stars are deemed to be, it would present the same roundness in the middle of the sun's disc as at the extreme edge, whereas they so much foreshorten and look so thin near that extremity, and &e on the other hand so broad and long toward the center, as to make it certain that these are flakes of little thickness or depth with respect. to their length and breadth.

Then as to its being observed ultimately that the same spots are sure to return after a certain period, do not believe that, Simplicio; those who said that were trying to deceive you. That this is so, you may see from their having said nothing to you about those that are generated or dissolved on the face of the sun far from the edge; nor told you a word about those which foreshorten, this being a necessary proof of their contiguity to the sun. The truth about the same spots returning is merely what is written in the said *Letters;* namely, that some of them are occasionally of such long duration that they do not disappear in a single revolution around the sun, which takes place in less than a month.

SIMP. To tell the truth, I have not made such long and careful observations that I can qualify as an authority on the facts of this matter; but certainly I wish to do so, and then to see whether I can once more succeed in reconciling what experience presents to us with what Aristotle teaches. For obviously two truths cannot contradict one another.

SALV. Whenever you wish to reconcile what your senses show you with the soundest teachings of Aristotle, you will have no trouble at all. Does not Aristotle say that because of the great distance, celestial matters cannot be treated very definitely?

SIMP. He does say so, quite clearly.

SALV. Does he not also declare that what sensible experience shows ought to be preferred over any argument, even one that seems to be extremely well founded? And does he not say this positively and without a bit of hesitation?

SIMP. He does.

SALV. Then of the two propositions, both of them Aristotelian doctrines, the second -- which says it is necessary to prefer the senses over arguments -- is a more solid and definite doctrine than the other, which holds the heavens to be inalterable. Therefore it is better Aristotelian philosophy to say "Heaven is alterable because my senses tell me so," than to say, "Heaven is inalterable because Aristotle was so persuaded by reasoning. Add to this that we possess a better basis for reasoning about celestial things than Aristotle did. He admitted such perceptions to be very difficult for him by reason of the distance from his senses, and conceded that one whose senses could better represent them would be able to philosophize about them with more certainty. Now we, thanks to the telescope, have brought the heavens thirty or forty times closer to us than they were to Aristotle, so that we can discern many things in them that he could not see; among other things these sunspots, which were absolutely invisible to him. Therefore we can treat of the heavens and the

sun more confidently than Aristotle could.

SAGR. I can put myself in Simplicios place and see that he is deeply moved by the overwhelming force of these conclusive arguments. But seeing on the other hand the great authority that Aristotle has gained universally; considering the number of famous interpreters who have toiled to explain his meanings; and observing that the other sciences, so useful and necessary to mankind, base a large pan of their value and reputation upon Aristotle's credit; Simplicio is confused and perplexed, and I seem to hear him say, "Who would there be to settle our controversies if Aristotle were to be deposed? What other author should we follow in the schools, the academies, the universities? What philosopher has written the whole of natural philosophy, so well arranged, without omitting a single conclusion? Ought we to desert that structure under which so many travelers have recuperated? Should we destroy that haven, that Prytaneum (note: Greek public hall where statesmen, heroes, and dignitaries were honored and entertained.) where so many scholars have taken refuge so comfortably; where, without exposing themselves to the inclemencies of the air, they can acquire a complete knowledge of the universe by merely turning over a few pages? Should that fort be leveled where one may abide in safety against all enemy assaults?"

I pity him no less than I should some fine gentleman who, having built a magnificent palace at great trouble and expense, employing hundreds and hundreds of artisans, and then beholding it threatened with ruin because of poor foundations, should attempt, in order to avoid the grief of seeing the walls destroyed, adorned as they are with so many lovely murals; or the columns fall, which sustain the superb galleries, or the gilded beams; or the doors spoiled, or the pediments and the marble cornices, brought in at so much cost -- should attempt, I say, to prevent the collapse with chains, props, iron bars, buttresses, and shores.

SALV. Well, Simplicio need not yet fear any such collapse; I undertake to insure him against damage at a much smaller cost. There is no danger that such a multitude of great, subtle, and wise philosophers will allow themselves to be overcome by one or two who bluster a bit. Rather, without even directing their pens against them, by means of silence alone, they place them in universal scorn and derision. It is vanity to imagine that one can introduce a new philosophy by refining this or that author, It is necessary first to teach the reform of the human mind and to render it capable of distinguishing truth from falsehood, which only God can do.

But where have we strayed, going from one argument to another? I shall not be able to get back to the path without guidance from your memory.

SIMP. I remember quite well. We were dealing with the reply of the *Anti-Tycho* to the objections against the immutability of the heavens. Among these you brought in this mater of the sunspots, nqt mentioned by its author, and J believe you wished to give consideration to his reply in the case of the new stars.

SALV. Now I remember the rest. Continuing this subject, ii seems to me that in the counter argument of the *Anti-Tycho* there are some things that ought to be criticized. First of all, if the two new stars, which that author can do no less than place in the highest regions of heaven, and which existed a long time and finally vanished, caused him no anxiety about insisting upon the inalterability of heaven simply because they were not unquestionably parts of heaven or mutations in the ancient stars, then to what purpose does he make all this fuss and bother about getting the comets away from the celestial regions at all costs? Would it not have been enough for him to say that they are not unquestionably parts of heaven and not mutations in the ancient stars, and hence that they do not prejudice in any way either the heavens or the doctrines of Aristotle?

In the second place I am not satisfied about his state of mind when he admits that any alterations which might be made in the stars would be destructive of the celestial prerogatives of incorruptibility, etc., since the stars are celestial things, as is obvious and as everybody admits, and when on the other hand he is not the least perturbed if the same alterations take place elsewhere in the expanse of heaven outside the stars

themselves. Does he perhaps mean to imply that heaven is not a celestial thing? I should think that the stars were called celestial things because of their being in the heavens, or because of their being made of heavenly material, and that therefore the heavens would be even more celestial than they; I could not say similarly that anything was more terrestrial than earth itself, or more igneous than fire.

Next, his not having made mention of the sunspots, which are conclusively proved to be produced and dissolved and to be situated next to the body of the sun and to revolve with it or in relation to it, gives me a good indication that this author may write more for the comforting of others than from his own convictions. I say this because he shows himself to be acquainted with mathematics, and it would be impossible for him not to be convinced by the proofs that such material is necessarily contiguous to the sun and undergoes generations and dissolutions so great that nothing of comparable size has ever occurred on earth. And if the generations and corruptions occurring on the very globe of the sun are so many, so great, and so frequent, while this can reasonably be called the noblest part of the heavens, then what argument remains that can dissuade us from believing that others take place on the other globes?

SAGR. I cannot without great astonishment -- I might say without great insult to my intelligence -- hear it attributed as a prime perfection and nobility of the natural and integral bodies of the universe that they are invariant, immutable, inalterable, etc., while on the other hand it is called a great imperfection to be alterable, generable, mutable, etc. For my part I consider the earth very noble and admirable precisely because of the diverse alterations, changes, generations, etc. that occur in it incessantly. If, not being subject to any changes, it were a vast desert of sand or a mountain of jasper, or if at the time of the flood the waters which covered it had frozen, and it had remained an enormous globe of ice where nothing was ever born or ever altered or changed, I should deem it a useless lump in the universe, devoid of activity and, in a word, superfluous and essentially nonexistent. This is exactly the difference between a living animal and a dead one; and I say the same of the moon, of Jupiter, and of all other world globes.

The deeper I go in considering the vanities of popular reasoning, the lighter and more foolish I find them. What greater stupidity can be imagined than that of calling jewels, silver, and gold "precious," and earth and soil "base"? People who do this ought to remember that if there were as great a scarcity of soil as of jewels or precious metals, there would not be a prince who would not spend a bushel of diamonds and rubies and a cartload of gold just to have enough earth to plant a jasmine in a little pot, or to sow an orange seed and watch it sprout, grow, and produce its handsome leaves, its fragrant flowers, and fine fruit. It is scarcity and plenty that make the vulgar take things to be precious or worthless; they call a diamond very beautiful because it is like pure water, and then would not exchange one for ten barrels of water. Those who so greatly exalt incorruptibility, inalterability, etc. are reduced to talking this way, I believe, by their great desire to go on living, and by the terror they have of death. They do not reflect that if men were immortal, they themselves would never have come into the world. Such men really deserve to encounter a Medusa's head which would transmute them into statues of jasper or of diamond, and thus make them more perfect than they are.

SALV. Maybe such a metamorphosis would not be entirely to their disadvantage, for I think it would be better for them not to argue than to argue on the wrong side.

SIMP. Oh, there is no doubt whatever that the earth is more perfect the way it is, being alterable, changeable, etc., than it would be if it were a mass of stone or even a solid diamond, and extremely hard and invariant. But to the extent that these conditions bring nobility to the earth, they would render less perfect the celestial bodies, in which they would be superfluous. For the celestial bodies -- that is, the sun, the moon, and the other stars, Which are ordained to have no other use than that of service to the earth -- need nothing more than motion and light to achieve their end.

SAGR. Has nature, then, produced and directed all these enormous, perfect, and most noble celestial bodies,

invariant, eternal, and divine. for no other purpose than to serve the changeable, transitory, and mortal earth? To serve that which you call the dregs of the universe, the sink of all uncleanness? Now to what purpose would the celestial bodies be made eternal, etc. in order to serve something transitory, etc.? Take away this purpose of serving the earth, and the innumerable host of celestial bodies is left useless and superfluous, since they have not and cannot have any reciprocal activities among themselves, all of them being inalterable, immutable, and invariant. For instance, if the moon is invariant, how would you have the sun or any other star act upon it? The action would doubtless have no more effect than an attempt to melt a large mass of gold by looking at it or by thinking about it. Besides, it seems to me that at such times as the celestial bodies are contributing to the generations and alterations on the earth, they too must be alterable. Otherwise I do not see how the influence of the moon or sun in causing generations on the earth would differ from placing a marble statue beside a woman and expecting children from such a union.

SIMP. Corruptibility, alteration, mutation, etc. do not pertain to the whole terrestrial globe, which as to its entirety is no less eternal than the sun or moon. But as to its external parts it is generable and corruptible, and it is certainly true that generations and corruptions are perpetual in those parts, and, as perpetual, that they require celestial and eternal operations. Therefore it is necessary that celestial bodies be eternal.

SAGR. This is all very well, but if there is nothing prejudicial to the immortality of the entire terrestrial globe in the corruptibility of its superficial pans, and if this generability, corruptibility, alterability, etc. give to it a great ornament and perfection, then why can you not and should you not likewise admit alterations, generations, etc. in the external parts of the celestial globes, adding these as an ornament without diminishing their perfection or depriving them of actions; even increasing those by making them operative not only upon the earth but reciprocally among themselves, and the earth also upon them?

SIMP. This cannot be, because the generations, mutations, etc. which would occur, say, on the moon, would be vain and useless, and nature makes nothing in vain.

SAGR. And why should they be vain and useless?

SIMP. Because we plainly see and feel that all generations, changes, etc. that occur on earth are either directly or indirectly designed for the use, comfort, and benefit of man. Horses are born to accommodate men; for the nutriment of horses, the earth produces hay and the clouds water it. For the comfort and nourishment of men are created herbs, cereals, fruits, beasts, birds, and fishes. In brief, if we proceed to examine and weigh carefully all these things, we shall find that the goal toward which all are directed is the need, the use, the comfort and the delight of men. Now of what use to the human race could generations ever be which might happen on the moon or other planets? Unless you mean that there are men also on the moon who enjoy their fruits; an idea which if not mythical is impious.

SAGR. I do not know nor do I suppose that herbs or plants or animals similar to ours are propagated on the moon, or that rains and winds and thunderstorms occur there as on the earth; much less that it is inhabited by men. Yet I still do not see that it necessarily follows that since things similar to ours are not generated there, no alterations at all take place, or that there cannot be things there that do change or are generated and dissolve; things not only different from ours, but so far from our conceptions as to be entirely unimaginable by us.

I am certain that a person born and raised in a huge forest among wild beasts and birds, and knowing nothing of the watery element, would never be able to frame in his imagination another world existing in nature differing from his, filled with animals which would travel without legs or fast‹beating wings, and not upon its surface alone like beasts upon the earth, but everywhere within its depths; and not only moving, but stopping motionless wherever they pleased, a thing which birds in the air cannot do. And that men lived there too, and built palaces and cities, and traveled with such ease that without tiring themselves at all they could

proceed to far countries with their families and households and whole cities. Now as I say, I am sure that such a man could not, even with the liveliest imagination, ever picture to himself fishes, the ocean, ships, fleets, and armadas. Thus, and more so, might it happen that in the moon, separated from us by so much greater an interval and made of materials perhaps much different from those on earth, substances exist and actions occur which are not merely remote from but completely beyond all our imaginings, lacking any resem-blance to ours and therefore being entirely unthinkable. For that which we imagine must be either something already seen or a composite of things and parts of things seen at different times; such are sphinxes, sirens, chimeras, centaurs, etc.

SALV. Many times have I given rein to my fancies about these things, and my conclusion is that it is indeed possible to discover some things that do not and cannot exist on the moon, but none which I believe can be and are there, except very generally; that is, things occupying it, acting and moving in it, perhaps in a very different way from ours, seeing and admiring the grandeur and beauty of the universe and of its Maker and Director and continually singing encomiums in His praise. I mean, in a word, doing what is so frequently decreed in the Holy Scriptures; namely, a perpetual occupation of all creatures in praising God.

SAGR. These are among the things which, speaking very generally, could be there. But I should like to hear you mention those which you believe cannot be there, as it must be possible for you to name them more specifically.

SALV. I warn you, Sagredo, that this will be the third time we have thus strayed imperceptibly, step by step, from our principal topic, and we shall get to the point of our argument but slowly if we make digressions. Therefore it will perhaps be good if we defer this matter, along with others we have agreed to put off until a special session.

SAGR. Please, now that we are on the moon, let us go on with things that pertain to it, so that we shall not have to make another trip over so long a road....

[*Salviati, using data from telescopic observations, describes the features of the moon and its resemblance to earth: it is spherical, mountainous, and has areas of contrasting brightness. Simplico argues that the moon is a perfectly smooth sphere made of celestial matter. The three engage in an extended argument about the nature of the moon.]*

SIMP. Therefore, in your opinion, the earth would make an appearance similar to that which we see in the moon, of at most two parts. But do you believe then that those great spots which are seen on the face of the moon are seas, and the brighter balance land, or some such thing?

SALV. What you are now asking me is the first of the differences that I think exist between the moon and the earth, which we had better hurry along with, as we are staying too long on the moon. I say then that if there were in nature only one way for two surfaces to be illuminated by the sun so that one appears lighter than the other, and that this were by having one made of land and the other of water, it would be necessary to say that the moon's surface was partly terrene and partly aqueous. But because there are more ways known to us that could produce the same effect, and perhaps others that we do not know of, I shall not make bold to affirm one rather than another to exist on the moon.

We have already seen that a bleached silver plate changes from white to dark by the touch of the burnisher; the watery part of the earth looks darker than the dry; on the ridges of mountains the wooded parts look much gloomier than the open and barren places because the plants cast a great deal of shadow while the clearings are lighted by the sun. Such a mixture of shadows is so effective that in sculptured velvet the color of the cut silk looks much darker than that of the uncut, because of shadows cast between one thread and another; and plain velvet is likewise much darker than taffeta made of the same silk. So if on the moon there

were things resembling dense forests, their aspect would probably be like that of the spots we see; a like difference would be created if they were seas; and, finally, there is nothing to prevent these spots being really of a darker color than the rest, for it is in that way that snow makes mountains appear brighter.

What is clearly seen in the moon is that the darker parts are all plains, with few rocks and ridges in them, though there are some. The brighter remainder is all fill of rocks, mountains, round ridges, and other shapes, and in particular there are great ranges of mountains around the spots. That the spots are flat surfaces we are certain, from observing that the boundary which separates the light and dark parts makes an even cut in traversing the spots, whereas in the bright parts it looks broken and jagged. But I do not know whether this evenness of surface is enough by itself to cause the apparent darkness, and I rather think not.

Quite apart from this, I consider the moon very different from the earth. Though I fancy to myself that its regions are not idle and dead, still I do not assert that life and motion exist there, and much less that plants, animals, or other things similar to ours are generated there. Even if they were, they would be extremely diverse, and far beyond all our imaginings. I am inclined to believe this because in the first place I think that the material of the lunar globe is not land and water, and this alone is enough to prevent generations and alterations similar to ours. But even supposing land and water on the moon, there are in any case two reasons that plants and animals similar to ours would not be produced there.

The first is that the varying aspects of the sun are so necessary for our various species that these could not exist at all without them. Now the behavior of the sun toward the earth is much different from that which it displays toward the moon. As to daily illumination, we on the earth have for the most part twenty -- four hours divided between day and night, but the same effect takes a month on the moon. The annual sinking and rising by which the sun causes the various seasons and the inequalities of day and night are finished for the moon in a month. And whereas for us the sun rises and sinks so much that between its maximum and minimum altitudes there lie forty -- seven degrees of difference (that is, as much as the distance between the tropics), for the moon it varies no more than ten degrees or a little less, which is the amount of the maximum latitudes of its orbit with respect to the ecliptic.

Now think what the action of the sun would be in the torrid zone if for fifteen days without pause it continued to beat down with its rays. It goes without saying that all the plants and herbs and animals would be destroyed; hence if any species existed there, they would be plants and animals very different from present ones.

In the second place, I am sure that there are no rains on the moon, because if clouds collected in any part of it, as around the earth, they would hide some of the things on the moon that we see with the telescope. Briefly, the scene would alter in some respect; an effect which I have never seen during long and diligent observations, having always discovered a very pure and uniform serenity.

SAGR. To this it might be replied that either there might be great dews or that it rains there during its nights; that is, when the sun does not light it up.

SALV. If from other appearances we had any signs that there were species similar to ours there, and only the occurrence of rains was lacking, we should be able to find this or some other condition to take their place, as happens in Egypt by the inundations of the Nile. But finding no event whatever like ours, of the many that would be required to produce similar effects, there is no point in troubling to introduce one only, and even that one not from sure observation but because of mere possibility. Besides, if I were asked what my basic knowledge and natural reason told me regarding the production there of things similar to or different from ours, I should always reply, "Very different and entirely unimaginable by us"; for this seems to me to fit with the richness of nature and the omnipotence of the Creator and Ruler.

SAGR. It always seems to me extreme rashness on the part of some when they want to make human abilities the measure of what nature can do. On the contrary, there is not a single effect in nature, even the least that exists, such that the most ingenious theorists can arrive at a complete understanding of it. This vain presumption of understanding everything can have no other basis than never understanding anything. For anyone who had experienced just once the perfect understanding of one single thing, and had truly tasted how knowledge is accomplished, would recognize that of the infinity of other truths he understands nothing.

SALV. Your argument is quite conclusive; in confirmation of it we have the evidence of those who do understand or have understood some thing; the more such men have known, the more they have recognized and freely confessed their little knowledge. And the wisest of the Greeks, so adjudged by the oracle, said openly that he recognized that he knew nothing.

SIMP. It must be said, then, that either the oracle or Socrates himself was a liar, the former declaring him the wisest, and the latter saying he knew himself the most ignorant.

SALV. Neither of your alternatives follows, since both pronouncements can be true. The oracle judges Socrates wisest above all other men, whose wisdom is limited; Socrates recognizes his knowing nothing relative to absolute wisdom which is infinite. And since much is the same part of infinite as little, or as nothing (for to arrive at an infinite number it makes no difference whether we accumulate thousands, tens, or zeros), Socrates did well to recognize his limited knowledge to be as nothing to the infinity which he lacked. But since there is nevertheless some knowledge to be found among men, and this is not equally distributed to all, Socrates could have had a larger share than others and thus have verified the response of the oracle.

SAGR. I think I understand this point quite well. Among men there exists the power to act, Simplicio, but it is not equally shared by all; and no doubt the power of an emperor is greater than that of a private person, but both are nil in comparison to Divine omnipotence. Among men there are some who understand agriculture better than others; but what has knowing how to plant a grapevine in a ditch got to do with knowing how to make it take root, draw nourishment, take from this some part good for building leaves, some other for forming tendrils, this for the bunches, that for the grapes, the other for the skins, all this being the work of most wise Nature? This is one single particular example of the innumerable works of Nature, and in this alone may be recognized an infinite wisdom; hence one may conclude that Divine wisdom is infinitely infinite.

SALV. Here is another example. Do we not say that the art of discovering a beautiful statue in a block of marble has elevated the genius of Michelangelo far, far above the ordinary minds of other men? Yet this work is nothing but the copying of a single attitude and position of the external and superficial members of one motionless man. Then what is it in comparison with a man made by Nature, composed of so many members, external and internal, of so many muscles, tendons, nerves, bones, that serve so many and such diverse motions? And what shall we say of the senses, of spiritual power, and finally of the understanding? May we not rightly say that the making of a statue yields by an infinite amount to the formation of a live man, even to the formation of the lowest worm?

SAGR. And what difference do you think there was between the dove of Archytas and a natural dove?

SIMP. Either I am without understanding or there is a manifest contradiction in this argument of yours. Among your greatest encomiums, if not indeed the greatest of all, is your praise for the understanding which you attribute to natural man. A little while ago you agreed with Socrates that his understanding was nil. Then you must say that not even Nature understood how to make an intellect that could understand.

SALY. You put the point very sharply, and to answer the objection it is best to have recourse to a philosophical distinction and to say that the human understanding can be taken in two modes, the *intensive* or the *extensive*. *Extensively*, that is, with regard to the multitude of intelligibles, which are infinite, the human understanding is as nothing even if it understands a thousand propositions; for a thousand in relation to infinity is zero. But taking man's understanding *intensively*, in so far as this term denotes understanding some proposition perfectly, I say that the human intellect does understand some of them perfectly, and thus in these it has as much absolute certainty as Nature itself has. Of such are the mathematical sciences alone; that is, geometry and arithmetic, in which the Divine intellect indeed knows infinitely more proposi-tions, since it knows all. But with regard to those few which the human intellect does understand, I believe that its knowledge equals the Divine in objective certainty, for here it succeeds in understanding necessity, beyond which there can be no greater sureness.

SIMP. This speech strikes me as very bold and daring.

SALV. These are very ordinary propositions and far from any shade of temerity or boldness. They do not detract in the least from the majesty of Divine wisdom, just as saying that God cannot undo what is done does not in the least diminish His omnipotence. But I question, Simplicio, whether your suspicion does not arise from your having taken my words equivocally. So in order to explain myself better, I say that as to the truth of the knowledge which is given by mathematical proofs, this is the same that Divine wisdom recognizes; but I shall concede to you indeed that the way in which God knows the infinite propositions of which we know some few is exceedingly more excellent than ours. Our method proceeds with reasoning by steps from one conclusion to another, while His is one of simple intuition. We, for example, in order to win a knowledge of some properties of the circle (which has an infinity of them), begin with one of the simplest, and, taking this for the definition of circle, proceed by reasoning to another property, and from this to a third, and then a fourth, and so on; but the Divine intellect, by a simple apprehension of the circle's essence, knows without time‹consuming reasoning all the infinity of its properties. Next, all these properties are in effect virtually included in the definitions of all things; and ultimately, through being infinite, are perhaps but one in their essence and in the Divine mind. Nor is all the above entirely unknown to the human mind either, but it is clouded with deep and thick mists, which become partly dispersed and clarified when we master some conclusions and get them so firmly established and so readily in our possession that we can run over them very rapidly. For, after all, what more is there to the square on the hypotenuse being equal to the squares on the other two sides, than the equality of two parallelograms on equal bases and between parallel lines? And is this not ultimately the same as the equality of two surfaces which when superimposed are not increased, but are enclosed within the same boundaries? Now these advances, which our intellect makes laboriously and step by step, run through the Divine mind like light in an instant; which is the same as saying that everything is always present to it.

I conclude from this that our understanding, as well in the manner as in the number of things understood, is infinitely surpassed by the Divine; but I do not thereby abase it so much as to consider it absolutely null. No, when I consider what marvelous things and how many of them men have understood, inquired into, and contrived, I recognize and understand only too clearly that the human mind is a work of God's, and one of the most excellent.

SAGR. I myself have many times considered in the same vein what you are now saying, and how great may be the acuteness of the human mind. And when I run over the many and marvelous inventions men have discovered in the arts as in letters, and then reflect upon my own knowledge, I count myself little better than miserable. I am so far from being able to promise myself, not indeed the finding out of anything new, but even the learning of what has already been discovered, that I feel stupid and confused, and am goaded by despair. If I look at some excellent statue, I say within my heart: "When will you be able to remove the

excess from a block of marble and reveal so lovely a figure hidden therein? When will you know how to mix different colors and spread them over a canvas or a wall and represent all visible objects by their means, like a Michelangelo, a Raphael, or a Titian?" Looking at what men have found out about ananging the musical intervals and forming precepts and rules in order to control them for the wonderful delight of the ear, when shall T be able to cease my amazement? What shall I say of so many and such diverse instruments? With what admiration the reading of excellent poets fills anyone who attentively studies the invention and interpretation of concepts And what shall I say of architecture? What of the art of navigation?

But surpassing all stupendous inventions, what sublimity of mind was his who dreamed of finding means to communicate his deepest thoughts to any other person, though distant by mighty intervals of place and time! Of talking with those who are in India; of speaking to those who are not yet born and will not he born for a thousand or ten thousand years; and with what facility, by the different arrangements of twenty characters upon a page!

Let this be the seal of all the admirable inventions of mankind and the close of our discussions for this day. The honest hours now being past, I think that Salviati might like to enjoy our cool ones in a gondola; and tomorrow I shall expect you both so that we may continue the discussions now begun.

End of the First Day

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Trial of Galileo Homepage

Dialogue Concerning the Two Chief World Systems

THE SECOND DAY

SALVIATI. Yesterday took us into so many and such great digressions twisting away from the main thread of our principal argument that I do not know whether I shall be able to go ahead without your assistance in putting me back on the track.

SAGR. I am not surprised that you should find yourself in some confusion, for your mind is as much filled and encumbered with what remains to be said as with what has been said. But I am simply a listener and have in my mind only the things I have heard, so perhaps I can put your discourse back on its path by briefly outlining these for you.

As I recall it, yesterday's discourse may be summarized as a preliminary examination of the two following opinions as to which is the more probable and reasonable. The first holds the substance of the heavenly bodies to be ingenerable, incorruptible, inalterable, invariant, and in a word free from all mutations except those of situation, and accordingly to be a quintessence (note: Literally, a fifth essence, distinct from the four elements of earth, water, air, and fire which were to be found within the lunar sphere.) most different from our generable, corruptible, alterable bodies. The other opinion, removing this disparity from the world's parts, considers the earth to enjoy the same perfection as other integral bodies of the universe; in short, to be a movable and a moving body no less than the moon, Jupiter, Venus, or any other planet. Later many detailed parallels were drawn between the earth and the moon. More comparisons were made with the moon than with other planets, perhaps from our having more and better sensible evidence about the former by reason of its lesser distance. And having finally concluded this second opinion to have more likelihood than the other, it seems to me that our next step should be to examine whether the earth must be considered immovable, as most people have believed up to the present, or mobile, as many ancient philosophers believed and as others of more recent times consider it; and, if movable, what its motion may be.

SALV. Now I know and recognize the signposts along our road. But before starting in again and going ahead, I ought to tell you that I question this last thing you have said, about our having concluded in favor of the opinion that the earth is endowed with the same properties as the heavenly bodies. For I did not conclude this, just as I am not deciding upon any other controversial proposition. My intention was only to adduce those arguments and replies, as much on one side as on the other-those questions and solutions which others have thought of up to the present time (together with a few which have occurred to me after long thought) -and then to leave the decision to the judgment of others.

SAGR. I allowed myself to be carried away by my own sentiments, and believing that what I felt in my heart ought to be felt by others too, I made that conclusion universal which should have been kept particular. This really was an error on my part, especially as I do not know the views of Simplicio, here present.

SIMP. I confess that all last night I was meditating on yesterday's material, and truly I find it to contain many beautiful considerations which are novel and forceful. Still, I am much more impressed by the authority of so many great authors, and in particular ... You shake your head, Sagredo, and smile, as if uttered some absurdity.

SAGR. I merely smile, but believe me, I am hardly able to keep from laughing, because I am reminded of

a situation that I witnessed not many years ago together with some friends of mine, whom I could name to you for that matter.

SALV. Perhaps you had better tell us about it so that Simplicio will not go on thinking your mirth was directed at him.

SAGR. I'll be glad to. One day I was at the home of a very famous doctor in Venice, where many persons came on account of their studies, and others occasionally came out of curiosity to see some anatomical dissection performed by a man who was truly no less learned than he was a careful and expert anatomist. It happened on this day that he was investigating the source and origin of the nerves, about which there exists a notorious controversy between the Galenist and Peripatetic doctors. The anatomist showed that the great trunk of nerves, leaving the brain and passing through the nape, extended on down the spine and then branched out through the whole body, and that only a single strand as fine as a thread arrived at the heart. Turning to a gentleman whom he knew to be a Peripatetic philosopher, and on whose account he had been exhibiting and demonstrating everything with unusual care, he asked this man whether he was at last satisfied and convinced that the nerves originated in the brain and not in the heart. The philosopher, after considering for awhile, answered: "You have made me see this matter so plainly and palpably that if Aristotle's text were not contrary to it, stating clearly that the nerves originate in the heart, I should be forced to admit it to be true."

SIMP. Sir, I want you to know that this dispute as to the source of the nerves is by no means as settled and decided as perhaps some people like to think.

SAGR. Doubtless it never will be, in the minds of such opponents. But what you say does not in the least diminish the absurdity of this Peripatetic's reply; who, as a counter to sensible experience, adduced no experiment or argument of Aristotle's, but just the authority of his bare *ipse dixit*.

SIMP. Aristotle acquired his great authority only because of the strength of his proofs and the profundity of his arguments. Yet one must understand him; and not merely understand him, but have such thorough familiarity with his books that the most complete idea of them may be formed, in such a manner that every saying of his is always before the mind. He did not write for the common people, nor was he obliged to thread his syllogisms together by the trivial ordinary method; rather, making use of the permuted method, he has sometimes put the proof of a proposition among texts that seem to deal with other things. Therefore one must have a grasp of the whole grand scheme, and be able to combine this passage with that, collecting together one text here and another very distant from it. There is no doubt that whoever has this skill will be able to draw from his books demonstrations of all that can be known; for every single thing is in them.

SAGR. My dear Simplicio, since having things scattered all over the place does not disgust you, and since you believe by the collection and combination of the various pieces you can draw the juice out of them, then what you and the other brave philosophers will do with Aristotle's texts, I shall do with the verses of Virgil and Ovid, making centos of them and explaining by means of these all the affairs of men and the secrets of nature. But why do I speak of Virgil, or any other poet" I have a little book, much briefer than Aristotle or Ovid, in which is contained the whole of science, and with very little study one may form from it the most complete ideas. It is the alphabet, and no doubt anyone who can properly Join and order this or that vowel and these or those consonants with one another can dig out of it the truest answers to every question, and draw from it instruction in all the arts and sciences. Just so does a painter, from the various simple colors placed separately upon his palette, by gathering a little of this with a bit of that and a trifle of the other, depict men, plants, buildings, birds, fishes, and in a word represent every visible object, without any eyes or feathers or scales or leaves or stones being on his palette. Indeed, it is necessary that

none of the things imitated nor parts of them should actually be among the colors, if you want to be able to represent everything; if there were feathers, for instance, these would not do to depict anything but birds or feather dusters.

SALV. And certain gentlemen still living and active were present when a doctor lecturing in a famous Academy, upon bearing the telescope described but not yet having seen it, said that the invention was taken from Aristotle. Having a text fetched, he found a certain place where the reason i's given why stars in the sky can be seen during daytime from the bottom of a very deep well. At this point the doctor said: "Here you have the well, which represents the tube; here the gross vapors, from whence the invention of glass lenses is taken; and finally here is the strengthening of the sight by the rays passing through a diaphanous medium which is denser and darker."

SAGR. This manner of "containing" everything that can be known is similar to the sense in which a block of marble contains a beautiful statue, or rather thousands of them; but the whole point lies in being able to reveal them. Even better we might say that it is like the prophecies of Joachim or the answers of the heathen oracles, which are understood only after the events they forecast have occurred.

SALV. And why do you leave out the prophecies of the astrologers, which are so clearly seen in horoscopes (or should we say in the configurations of the heavens) after their fulfillment?

SAGR. It is in this way that the alchemists, led on by their madness, find that the greatest geniuses of the world never really wrote about anything except how to make gold; but in order to tell this without revealing it to the vulgar, this fellow in one manner and that one in another have whimsically concealed it under various disguises. And a very amusing thing it is to hear their comments upon the ancient poets, revealing the important mysteries hidden behind their stories--what the loves of the moon mean, and her descent to the earth for Endymion; her displeasure with Acteon; the significance of Jupiter's turning himself into a rain of gold, or into a fiery flame; what great secrets of the art there are in Mercury the interpreter, in Pluto's kidnapings, and in golden boughs.

SIMP. I believe, and to some extent f know, that the world does not lack certain giddy brains, but their folly should not redound to the discredit of Aristotle, of whom it seems to me you sometimes speak with too little respect. His antiquity alone, and the mighty name he has acquired among so many men of distinguished mind, should be enough to earn him respect among all the learned.

SALV. That is not quite how matters stand, Simplicio. Some of his followers are so excessively timid that they give us occasion (or more correctly would give us occasion if we credited their triflings) to think less of him. Tell me, are you so credulous as not to understand that if Aristotle had been present and heard this doctor who wanted to make him inventor of the telescope, he would have been much angrier with him than with those who laughed at this doctor and his interpretations? Is it possible for you to doubt that if Anistotle should see the new discoveries in the sky he would change his opinions and correct his books and embrace the most sensible doctrines, casting away from himself those people so weak-minded as to be induced to go on abjectly maintaining everything he had ever said? Why, if Aristotle had been such a man as they imagine, he would have been a man of intractable mind, of obstinate spirit, and barbarous soul; a man of tyrannical will who, regarding all others as silly sheep, wished to have his decrees preferred over the senses, experience, and nature itself It is the followers of Aristotle who have crowned him with authority, not he who has usurped or appropriated it to himself And since it is handier to conceal oneself under the cloak of another than to show one's face in open court, they dare not in their timidity get a single step away from him, and rather than put any alterations into the heavens of Aristotle, they want to deny out of hand those that they see in nature's heaven.

SAGR. Such people remind me of that sculptor who, having transformed a huge block of marble into the image of a Hercules or a thundering Jove, I forget which, and having with consummate art made it so lifelike and fierce that it moved everyone with terror who beheld it, he himself began to be afraid, though all its vivacity and power were the work of his own hands; and his terror was such that he no longer dared affront it with his mallet and chisel.

SALV. I often wonder how it can be that these strict supporters of Aristotle's every word fail to perceive how great a hindrance to his credit and reputation they are, and how the more they desire to increase his authority, the more they actually detract from it, For when I see them being obstinate about sustaining propositions which I personally know to be obviously false, and wanting to persuade me that what they are doing is truly philosophical and would be done by Aristotle himself, it much weakens my opinion that he philosophized correctly about other matters more recondite to me. If I saw them give in and change their opinions about obvious truths, I should believe that they might have sound proofs for those in which they persisted and which I did not understand or had not heard.

SAGR. Or truly, if it seemed to them that they staked too much of their own reputation and of Aristotle's in confessing that they did not know this or that conclusion discovered by someone else, would it not be a lesser evil for them to seek it among his texts by the collection of various of these according to the practice recommended by Simplicio? For if all things that can be known are in these texts, then it must follow that they can be discovered there.

SALV. Sagredo, do not sneer at this prudent scheme, which it seems to me you propose sarcastically. For it is not long since a famous philosopher composed a book on the soul in which, discussing Aristotle's opinion as to its mortality or immortality, he adduced many texts beyond those already quoted by Alexander. As to those, he asserted that Aristotle was not even dealing with such matters there, let alone deciding anything about them, and he gave others which he himself had discovered in various remote places and which tended to the damaging side. Being advised that this would make trouble for him in getting a license to publish it, he wrote back to his friend that he would nevertheless get one quickly, since if no other obstacle came up he would have no difficulty altering the doctrine of Aristotle; for with other texts and other expositions he could maintain the contrary opinion, and it would still agree with the sense of Aristotle.

SAGR. Oh, what a doctor this is' I am his to command; for he will not let himself be imposed upon by Aristotle, but Will lead him by the nose and make him speak to his own purpose! See how important it is to know how to take time by the forelock! One ought not to get into the position of doing business with Hercules when he is under the Furies and enraged, but rather when he is telling stories among the Lydian maids.

Oh, the inexpressible baseness of abject minds! To make themselves slaves willingly; to accept decrees as inviolable; to place themselves under obligation and to call themselves persuaded and convinced by arguments that are so "powerful" and "clearly conclusive" that they themselves cannot tell the purpose for which they were written, or what conclusion they serve to prove' But let us call it a greater madness that among themselves they are even in doubt whether this very author held to the affirmative or the negative side. Now what is this but to make an oracle out of a log of wood, and run to it for answers; to fear it, revere it, and adore it?

SIMP. But if Aristotle is to be abandoned, whom shall we have for a guide in philosophy? Suppose you name some author.

SALV. We need guides in forests and in unknown lands, but on plains and in open places only the blind need guides. It is better for such people to stay at home, but anyone with eyes in his head and his wits about him could serve as a guide for them. In saying this, I do not mean that a person should not listen to Aristotle; indeed, I applaud the reading and careful study of his works, and I reproach only those who give themselves up as slaves to him in such a way as to subscribe blindly to everything he says and take it as an inviolable decree without looking for any other reasons. This abuse carries with it another profound disorder, that other people do not try harder to comprehend the strength of his demonstrations. And what is more revolting in a public dispute, when someone is dealing with demonstrable conclusions, than to hear him interrupted by a text (often written to some quite different purpose) thrown into his teeth by an opponent? If, indeed, you wish to continue in this method of studying, then put aside the name of philosophers and call yourselves historians, or memory experts; for it is not proper that those who never philosophize should usurp the honorable title of philosopher.

But we had better get back to shore, lest we enter into a boundless ocean and not get out of it all day. So put forward the arguments and demonstrations, Simplicio--either yours or Aristotle's--but not just texts and bare authorities, because our discourses must relate to the sensible world and not to one on paper. And since in yesterday's argument the earth was lifted up out of darkness and exposed to the open sky, and the attempt to number it among the bodies we call heavenly was shown to be not so hopeless and prostrate a proposition that it remained without a spark of life, we should follow this up by examining that other proposition which holds it to be probable that the earth is fixed and utterly immovable as to its entire globe, and see what chance there is of making it movable, and with what motion.

Now because I am undecided about this question, whereas Simplicio has his mind made up with Aristotle on the side of immovability, he shall give the reasons for his opinion step by step, and I the answers and the arguments of the other side, while Sagredo shall tell us the workings of his mind and the side toward which he feels it drawn.

SAGR. That suits me very well, provided that I retain the freedom to bring up whatever common sense may dictate to me from time to time.

SALV. Indeed, I particularly beg you to do so; for I believe that writers on the subject have left out few of the easier and, so to speak, more material considerations, so that only those are lacking and may be wished for which are subtler and more recondite. And to look into these, what ingenuity can be more fitting than that of Sagredo's acute and penetrating wit?

SAGR. Describe me as you like, Salviati, but please let us not get into another kind of digression--the ceremonial. For now I am a philosopher, and am at school and not at court *(al Broio)*.

SALV. Then let the beginning Of OUT reflections be the consideration that whatever motion comes to be attributed to the earth must necessarily remain imperceptible to us and as if nonexistent, so long as we look only at terrestrial objects; for as inhabitants of the earth, we consequently participate in the same motion. But on the other hand it is indeed just as necessary that it display itself very generally in all other visible bodies and objects which, being separated from the earth, do not take part in this movement. So the true method of investigating whether any motion can be attributed to the earth, and if so what it may be, is to observe and consider whether bodies separated from the earth exhibit some appearance of motion which belongs equally to all. For a motion which is perceived only, for example, in the moon, and which does not affect Venus or Jupiter or the other stars, cannot in any way be the earth's or anything but the moon's.

Now there is one motion which is most general and supreme over all, and it is that by which the sun, moon, and all other planets and fixed stars--in a word, the whole universe, the earth alone excepted--appear to be moved as a unit from east to west in the space of twenty-four hours. This, in so far as first appearances are concerned, may just as logically belong to the earth alone as to the rest of the universe, since the same appearances would prevail as much in the one situation as in the other. Thus it is that Aristotle and Ptolemy, who thoroughly understood this consideration, in their attempt to prove the earth immovable do not argue against any other motion than this diurnal one, though Aristotle does drop a hint against another motion ascribed to it by an ancient writer of which we shall speak in the proper place.

SAGR. I am quite convinced of the force of your argument, but it raises a question for me from which I do not know how to free myself, and it is this: Copernicus attributed to the earth another motion than the diurnal. By the rule just affirmed, this ought to remain imperceptible to all observations on the earth, but be visible in the rest of the universe. It seems to me that one may deduce as a necessary consequence either that he was grossly mistaken in assigning to the earth a motion corresponding to no appearance in the heavens generally, or that if the correspondent motion does exist, then Ptolemy was equally at fault in not explaining it away, as he explained away the other.

SALV. This is very reasonably questioned, and when we come to treat of the other movement you Will see how greatly Copernicus surpassed Ptolemy in acuteness and penetration of mind by seeing what the latter did not-I mean the wonderful correspondence with which such a movement is reflected in all the other heavenly bodies. But let us postpone this for the present and return to the first consideration, With respect to which I shall set forth, commencing with the most general things, those reasons which seem to favor the earth's motion, so that we may then hear their refutation from Simplicio.

First, let us consider only the immense bulk of the starry sphere in contrast With the smallness of the terrestrial globe, which is contained in the former so many millions of times. Now if we think of the velocity of motion required to make a complete rotation in a single day and night, I cannot persuade myself that anyone could be found who would think it the more reasonable and credible thing that it was the celestial sphere which did the turning, and the terrestrial globe which remained fixed.

SAGR. If, throughout the whole variety of effects that could exist in nature as dependent upon these motions, all the same consequences followed indifferently to a hairsbreadth from both positions, still my first general impression of them would be this: I should think that anyone who considered it more reasonable for the whole universe to move in order to let the earth remain Fixed would be more irrational than one who should climb to the top of your cupola just to get a view of the city and its environs, and then demand that the whole countryside should revolve around him so that he would not have to take the trouble to turn his head. Doubtless there are many and great advantages to be drawn from the new theory and not from the previous one (which to my mind is comparable with or even surpasses the above in absurdity), making the former more credible than the latter. But perhaps Aristotle, Ptolemy, and Simplicio ought to marshal their advantages against us and set them forth, too, if such there are; otherwise it will be clear to me that there are none and cannot be any.

SALV. Despite much thinking about it, I have not been able to find any difference, so it seems to me I have found that there can be no difference; hence I think it vain to seek one further. For consider: Motion, in so far as It is and acts as motion, to that extent exists relatively to things that lack it; and among things which all share equally in any motion, it does not act, and is as if It did not exist. Thus the goods with which a ship is laden leaving Venice, pass by Corfu, by Crete, by Cyprus and go to Aleppo. Venice, Corfu, Crete, etc. stand still and do not move with the ship; but as to the sacks, boxes, and bundles with which the boat is laden and with respect to the ship itself, the motion from Verflice to Syria

is as nothing, and in no way alters their relation among themselves. This is so because it is common to all of them and all share equally in it. If, from the cargo in the ship, a sack were shifted from a chest one single inch, this alone would be more of a movement for it than the two-thousand-mile journey made by all of them together.

SIMP. This is good, sound doctrine, and entirely Peripatetic.

SALV. I should have thought it somewhat older. And I question whether Aristotle entirely understood it when selecting it from some good school of thought, and whether he has not, by altering it in his Writings, made it a source of confusion among those who wish to maintain everything he said. When he wrote that everything which is moved is moved upon something immovable, I think he only made equivocal the saying that whatever moves, moves with respect to something motionless. This proposition suffers no difficulties at all, whereas the other has many.

SAGR. Please do not break the thread, but continue with the argument already begun.

SALV. It is obvious, then, that motion which is common to many moving things is idle and inconsequential to the relation of these movables among themselves, nothing being changed among them, and that it is operative only in the relation that they have with other bodies lacking that motion, among which their location is changed. Now, having divided the universe into two parts, one of which is necessarily movable and the other motionless, it is the same thing to make the earth alone move, and to move all the rest of the universe, so far as concerns any result which may depend upon such movement. For the action of such a movement is only in the relation between the celestial bodies and the earth, which relation alone is changed. Now if precisely the same effect follows whether the earth is made to move and the rest of the universe stay still, or the earth alone remains fixed while the whole universe shares one motion, who is going to believe that nature (which by general agreement does not act by means of many things when it can do so by means of few) has chosen to make an immense number of extremely large bodies move with inconceivable velocities, to achieve what could have been done by a moderate movement of one single body around its own center?

SIMP. I do not quite understand how this very great motion is as nothing for the sun, the moon, the other planets, and the innumerable host of the fixed stars. Why do you say it is nothing for the sun to pass from one meridian to the other, rise above this horizon and sink beneath that, causing now the day and now the night; and for the moon, the other planets, and the fixed stars to vary similarly?

SALV. Every one of these variations which you recite to me is nothing except in relation to the earth. To see that this is true, remove the earth; nothing remains in the universe of rising and setting of the sun and moon, nor of horizons and meridians, nor day and night and in a word from this movement there will never originate any changes in the moon or sun or any stars you please, fixed or moving. All these changes are in relation to the earth, all of them meaning nothing except that the sun shows itself now over China, then to Persia, afterward to Egypt, to Greece, to France, to Spain, to America, etc. And the same holds for the moon and the rest of the heavenly bodies, this effect taking place in exactly the same way if, without embroiling the biggest part of the universe, the terrestrial globe is made to revolve upon itself

And let us redouble the difficulty with another very great one, which is this. If this great motion is attributed to the heavens, it has to be made in the opposite direction from the specific motion of all the planetary orbs, of which each one incontrovertibly has its own motion from west to east, this being very gentle and moderate, and must then be made to rush the other way; that is, from east to west, with this very rapid diurnal motion. Whereas by making the earth itself move, the contrariety of motions is removed, and the single motion from west to east accommodates all the observations and satisfies them all

completely.

SIMP. As to the contrariety of motions, that would matter little, since Aristotle demonstrates that circular motions are not contrary to one another, and their opposition cannot be called true contrariety.

SALV. Does Aristotle demonstrate that, or does he just say it because it suits certain designs of his? If, as he himself declares, contraries are those things which mutually destroy each other, I cannot see how two movable bodies meeting each other along a circular line conflict any less than if they had met along a straight line.

SAGR. Please stop a moment. Tell me, Simplicto, when two knights meet tilting in an open field, or two whole squadrons, or two fleets at sea go to attack and smash and sink each other, would you call their encounters contrary to one another?

SIMP. I should say they were contrary.

SAGR. Then why are two circular motions not contrary? Being made upon the surface of the land or sea, which as you know is spherical, these motions become circular. Do you know what circular motions are not contrary to each other, Simplicio? They are those of two circles which touch from the outside; one being turned, the other naturally moves the opposite way. But if one circle should be inside the other, it Is I . impossible that their motions should be made in opposite directions without their resisting each other.

SALV. "Contrary" or "not contrary," these are quibbles about words, but I know that with facts It is a much simpler and more natural thing to keep everything with a single motion than to introduce two, whether one wants to call them contrary or opposite. But I do not assume the introduction of two to be impossible, nor do I pretend to draw a necessary proof from this; merely a greater probability. The improbability I . s shown for a third time in the relative disruption of the order which we surely see existing among those heavenly bodies whose circulation is not doubtful, but most certain. This order is such that the greater orbits complete their revolutions in longer times, and the lesser in shorter; thus Saturn, describing a greater circle than the other planets, completes it in thirty years; Jupiter revolves in its smaller one in twelve years, Mars in two; the moon covers its much smaller circle in a single month. And we see no less sensibly that of the satellites of Jupiter (*stelle, Medicee*), (note: Galileo had named the moons he discovered the "Medicean stars" in honor of his patron, the Grand Duke of Tuscany, to whom this book was dedicated.) the closest one to that planet makes its revolution in a very short time, that is in about forty-two hours, the next, in three and a half days; the third in seven days and the most distant in sixteen. And this very harmonious trend will not be a bit altered if the earth is made to move on itself in twenty-four hours. But if the earth is desired to remain motionless, it is necessary, after passing from the brief period of the moon to the other consecutively larger ones, and ultimately to that of Mars in two years, and the greater one of Jupiter in twelve, and from this to the still larger one of Saturn, whose period is thirty years--it is necessary, I say, to pass on beyond to another incomparably larger sphere, and make this one finish an entire revolution in twenty-four hours. Now this is the minimum disorder that can be introduced, for if one wished to pass from Saturn's sphere to the stellar, and make the latter so much greater than Saturn's that it would proportionally be suited to a very slow motion of many thousands of years, a much greater leap would be required to pass beyond that to a still larger one and then make that revolve in twenty-four hours. But by giving mobility to the earth, order becomes very well observed among the periods; from the very slow sphere of Saturn one passes on to the entirely immovable fixed stars, and manages to escape a fourth difficulty necessitated by supposing the stellar sphere to be movable. This difficulty is the immense disparity between the motions of the stars, some of which would be moving very rapidly in vast circles, and others very slowly in little tiny circles, according as they are located farther from or closer to the poles. This is indeed a nuisance, for just as we see that all those bodies whose motion is undoubted move

in large circles, so it would not seem to have been good judgment to arrange bodies in such a way that they must move circularly at immense distances from the center, and then make them move in little tiny circles.

Not only will the size of the circles and consequently the velocities of motion of these stars be very diverse from the orbits and motions of some others, but (and this shall be the fifth difficulty) the same stars will keep changing their circles and their velocities, since those which two thousand years ago were on the celestial equator, and which consequently described great circles with their motion, are found in our time to be many degrees distant, and must be made slower in motion and reduced to moving in smaller circles. Indeed, it is not impossible that a time will come when some of the stars which in the past have always been moving will be reduced, by reaching the pole, to holding fast, and then after that time will start moving once more; whereas all those stars which certainly do move describe, as I said, very large circles In their orbits and are unchangeably preserved in them.

For anyone who reasons soundly, the unlikelihood is increased--and this is the sixth difficulty--by the incomprehensibility of what is called the "solidity" of that very vast sphere in whose depths are firmly fixed so many stars which, without changing place in the least among themselves, come to be carried around so harmoniously with such a disparity of motions. If, however, the heavens are fluid (as may much more reasonably be believed) so that each star roves around in it by itself, what law will regulate their motion so that as seen from the earth they shall appear as if made into a single sphere" For this to happen, it seems to me that it is as much more effective and convenient to make them immovable than to have them roam around, as it is easier to count the myriad tiles set in a courtyard than to number the troop of children running around on them.

Finally, for the seventh objection, if we attribute the diurnal rotation to the highest heaven, then this has to be made of such strength and power as to carry with it the innumerable host of fixed stars, all of them vast bodies and much larger than the earth, as well as to carry along the planetary orbs despite the fact that the two move naturally in opposite ways. Besides this, one must grant that the element of fire and the greater part of the air are likewise hurried along, and that only the little body of the earth remains defiant and resistant to such power. This seems to me to be most difficult; I do not understand why the earth, a suspended body balanced on its center and indifferent to motion or to rest, placed in and surrounded by an enclosing fluid, should not give in to such force and be carried around too. We encounter no such objections if we give the motion to the earth, a small and trifling body in comparison with the universe, and hence unable to do it any violence.

SAGR. I am aware of some ideas whirling around in my own imagination which have been confusedly roused in me by these arguments. If I wish to keep my attention on the things about to be said, I shall have to try to get them in better order and to place the proper construction upon them, if possible. Perhaps it will help me to express myself more easily if I proceed by interrogation. Therefore I ask Simplicio, first, whether he believes that the same simple movable body can naturally partake of diverse movements, or whether only a single motion suits it, this being its own natural one.

SIMP. For a simple movable body there can be but a single motion, and no more, which suits it naturally; any others it can possess only incidentally and by participation. Thus when a man walks along the deck of a ship, his own motion is that of walking, while the motion which takes him to port is his by participation; for he could never arrive there by walking if the ship did not take him there by means of its motion.

SAGR. Second, tell me about this motion which is communicated to a movable body by participation, when it itself is moved by some other motion different from that in which it participates. Must this shared motion in turn reside in some subject, or can it indeed exist in nature without other support?

SIMP. Aristotle answers all these questions for you. He tells you that just as there is only one motion for one movable body, so there is but one movable body for that motion. Consequently no motion can either exist or even be imagined except as inhering In its subject.

SAGR. Now in the third place I should like you to tell me whether you believe that the moon and the other planets and celestial bodies have their own motions, and what these are.

SIMP. They have, and they are those motions in accordance with which they run through the zodiac--the moon in a month, the sun in a year, Mars in two, the stellar sphere in so many thousands. These are their own natural motions.

SAGR. Now as to that motion with which the fixed stars, and with them all the planets, are seen rising and setting and returning to the east every twenty-four hours. How does that belong to them?

SIMP. They have that by participation.

SAGR. Then it does not reside in them; and neither residing in them, nor being able to exist without some subject to reside in, it must be made the proper and natural motion of some other sphere.

SIMP. As to this, astronomers and philosophers have discovered another very high sphere, devoid of stars, to which the diurnal rotation naturally belongs. To this they have given the name *primum mobile;* this speeds along with it all the inferior spheres, contributing to and sharing with them its motion.

SAGR. But when all things can proceed in most perfect harmony without Introducing other huge and unknown spheres; without other movements or imparted speedings; with every sphere having only its simple motion, unmixed with contrary movements, and with everything taking place in the same direction, as must be the case if all depend upon a single principle, why reject the means of doing this, and give assent to such outlandish things and such labored conditions?

SIMP. The point is to find a simple and ready means.

SAGR. This seems to me to be found, and quite elegantly. Make the earth the *primum mobile*; that is, make it revolve upon itself in twenty-four hours in the same way as all the other spheres. Then, without its imparting such a motion to any other planet or star, all of them will have their risings, settings, and in a word all their other appearances.

SIMP. The crucial thing is being able to move the earth without causing a thousand inconveniences.

SALV. All inconveniences will be removed as you propound them. Up to this point, only the first and most general reasons have been mentioned which render it not entirely improbable that the daily rotation belongs to the earth rather than to the rest of the universe. Nor do I set these forth to you as inviolable laws, but merely as plausible reasons. For I understand very well that one single experiment or conclusive proof to the contrary would suffice to overthrow both these and a great many other probable arguments. So there is no need to stop here; rather let us proceed ahead and bear what Simplicio answers, and what greater probabilities or firmer arguments be adduces on the other side.

SIMP. First I shall say some things in general about all these considerations taken together, and then get down to certain particulars.

It seems to me that you base your case throughout upon the greater ease and simplicity of producing the

same effects. As to their causation, you consider the moving of the earth alone equal to the moving of all the rest of the universe except the earth, while from the standpoint of action, you consider the former much easier than the latter. To this I answer that it seems that way to me also when I consider my own powers, which are not finite merely, but very feeble. But with respect to the power of the Mover, which is infinite, it is just as easy to move the universe as the earth, or for that matter a straw. And when the power is infinite, why should not a great part of it be exercised rather than a small? From this it appears to me that the general argument is ineffective.

SALV. If I had ever said that the universe does not move because of any lack of power in the Mover, I should have been mistaken, and your correction would be opportune; I grant you that it is as easy for an infinite force to move a hundred thousand things as to move one. But what I have been saying was with regard not to the Mover, but only the movables; and not with regard to their resistance alone, which is certainly less for the earth than for the universe, but with regard to other particulars considered just now.

Next, as to your saying that a great part of an infinite power may better be exercised than a small part, I reply to you that one part of the infinite is not greater than another, when both are-finite; nor can it be said of an infinite number that a hundred thousand is a greater part than two I . s, though the former is fifty thousand times as great as the latter. And if what is required in order to move the universe is a finite power, then even though this would be very large in comparison with what would be required to move the earth alone, nevertheless a greater part of the infinite power would not thereby be employed, nor would that which remained idle be less than infinite. Hence to apply a little more or less power for a particular effect is insignificant. Besides, the operations of such power do not have for their end and goal the diurnal movement alone, for there are many other motions of the universe that we know of, and there may be very many more unknown to us.

Giving our attention, then, to the movable bodies, and not questioning that it is a shorter and readier operation to move the earth than the universe, and paying attention to the many other simplifications and conveniences that follow from merely this one, it is much more probable that the diurnal motion belongs to the earth alone than to the rest of the universe excepting the earth. This is supported by a very true maxim of Aristotle's which teaches that *frustra fit per plura quod potest fieri per pauciora*.

SIMP. In referring to this axiom you have left out one little clause that means everything, especially for our present purposes. The detail left out is aeque bene; hence it is necessary to examine whether both assumptions can satisfy us *equally well* in every respect.

SALV. Finding out whether both positions satisfy us equally well will be included in the detailed examination of the appearances which they have to satisfy. For we have argued *ex hypothesi* up to now, and Will continue to argue so, assuming that both positions are equally adapted to the fulfillment of all the appearances. So I suspect that this detail which you declare to have been omitted by me was rather superfluously added by you. Saying "equally well" names a relation, which necessarily requires at I east two terms, one thing not being capable of being related to itself, one cannot say, for example, that quiet is equally good with quiet. Therefore to say: "It is pointless to use many to accomplish what may be done with fewer" implies that what is to be done must be the same thing, and not two different things. And because the same thing cannot be said to be equally well done With itself, the addition of the phrase "equally well" Is superfluous, and a relation with only one term,

SAGR. If we do not want to repeat what happened yesterday, please get back to the point; and you, Simplicio, begin producing those difficulties that seem to you to contradict this new arrangement of the universe.

SIMP. The arrangement is not new; rather, it is most ancient, as is shown by Aristotle refuting it, the following being his refutations :

"First, whether the earth is moved either in itself, being placed in the center, or in a circle, being removed from the center, it must be moved with such motion by force, for this is not its natural motion. Because if it were, it would belong also to all its particles. But every one of them is moved along a straight line toward the center. Being thus forced and preternatural, it cannot be everlasting. But the world order is eternal; therefore, etc.

"Second, it appears that all other bodies which move circularly lag behind, and are moved with more than one motion, except the *primum mohile*. Hence it would be necessary that the earth be moved also with two motions; and if that were so, there would have to be variations in the fixed stars. But such are not to be seen; rather, the same stars always rise and set in the same place without any vaniations.

"Third, the natural motion of the parts and of the whole is toward the center of the universe, and for that reason also it rests therein." He then discusses the question whether the motion of the parts is toward the center of the universe or merely toward that of the earth, concluding that their own tendency is to go toward the former, and that only accidentally do they go toward the latter, which question was argued at length yesterday.

Finally he strengthens this with a fourth argument taken from experiments with heavy bodies which, failing from a height, go perpendicularly to the surface of the earth. Similarly, projectiles thrown vertically upward come down again perpendicularly by the same line, even though they have been thrown to immense height. These arguments are necessary proofs that their motion is toward the center of the earth, which, without moving in the least, awaits and receives them.

He then hints at the end that astronomers adduce other reasons in confirmation of the same conclusions--that the earth is in the center of the universe and immovable. A single one of these is that all the appearances seen In the movements of the stars correspond with this central position of the earth, which correspondence they would not otherwise possess. The others, adduced by Ptolemy and other astronomers, I can give you now if you like; or after you have said as much as you want to In reply to these of Aristotle.

SALV. The arguments produced on this matter are of two kinds. Some pertain to terrestrial events without relation to the stars, and others are drawn from the appearances and observations of celestial things. Aristotle's arguments are drawn mostly from the things around us, and he leaves the others to the astronomers. Hence it will be good, if it seems so to you, to examine those taken from earthly experiments, and thereafter we shall see to the other sort. And since some such arguments are adduced by Ptolemy, Tycho, and other astronomers and philosophers, in addition to their accepting, confirming, and supporting those of Aristotle, these may all be taken together in order not to have to give the same or similar answers twice. Therefore. Simplicio, present them, if you will; or, if you want me to relieve you of that burden, I am at your service.

SIMP. It will be better for you to bring them up, for having given them greater study you will have them readier at hand, and in great number too....

SALV. But is it not your opinion, and that of the author and of Aristotle and Ptolemy and all their followers, that earth, water, and air are equally of such a nature as to be constituted immovable about the center?

SIMP. That is taken as an irrefutable truth.

SALV. Then the argument for the different natures of these elements and elemental things is not taken from this common natural condition of rest with respect to the center, but must be learned by taking notice of other qualities which they do not have in common. Therefore whoever should take from the elements only this common state of rest, and leave them all their other actions, would not in the least obstruct the road which leads us to an awareness of their essences.

Now Copernicus takes from them nothing except this common rest, leaving to them weight or lightness; motion up or down, slow or fast; rarity and density; the qualities of beat, cold, dryness, moistness; and, in a word, everything else. Hence no such absurdity as this author imagines exists anywhere in the Copernican position. Agreement in an identical motion means neither more nor less than agreement in an identical state of rest, so far as any diversification or nondiversification of natures is concerned. Now tell me if he has other opposing arguments.

SIMP. There follows a fourth objection, taken once again from an observation of nature. It is that bodies of the same kind have motions which agree in kind, or else they agree in rest. But in Copernicus's theory, bodies agreeing in kind and quite similar to each other would have great discrepancies as to motion, or even be diametrically opposed. For stars, so very similar to one another, would nevertheless have such dissimilar motions that six planets would perpetually go around, while the sun and the fixed stars would remain forever unmoved.

SALV. The form of this argumentation appears to me valid, but I believe that its content or its application is at fault, and if the author were to persist in this assumption the consequences would run directly counter to his. The method of argument is this:

Among world bodies, there are six which perpetually move; these are the six planets. Of the others (that is, the earth, the sun, and the fixed stars) the question is which move and which stand still. If the earth stands still, the sun and the fixed stars necessarily move, and it may also be that the sun and the fixed stars are motionless if the earth is moving. This matter being in question, we inquire which ones may more suitably have motion attributed to them, and which ones rest.

Common sense says that motion ought to be deemed to belong to those which agree better in kind and in essence with the bodies which unquestionably do move, and rest to those which differ most from them. Eternal rest and perpetual motion being very different events, it is evident that the nature of an ever-moving body must be quite different from that of one which is always fixed. Let us therefore find out, when in doubt about motion and rest, whether by way of some other relevant condition we can investigate which--the earth, or the sun and the fixed stars--more resembles those bodies which are known to be movable,

Now behold how nature, favoring our needs and wishes, presents us with two striking conditions no less different than motion and rest; they are lightness and darkness--that is, being brilliant by nature or being obscure and totally lacking in light. Therefore bodies shining with internal and external splendor are very different in nature from bodies deprived of all light. Now the earth is deprived of light; most splendid in itself is the sun, and the fixed stars are no less so. The six moving planets entirely lack light, like the earth; therefore their essence resembles the earth and differs from the sun and the fixed stars. Hence the earth moves, and the sun and the stellar sphere are motionless.

SIMP. But the author will not concede that the six planets are dark, and will stand firm upon that denial;

or else he will argue the great conformity in nature between the six planets and the sun and fixed stars, as well as the contrast between the latter and the earth, with respect to conditions other than those of darkness and light. Indeed, I now see that here In the fifth objection, which follows, there is set forth the great disparity between the earth and the heavenly bodies. He writes that there would be great confusion and trouble in the system of the universe and among its parts, according to the Copernican hypothesis, because of its placing among the heavenly bodies (immutable and incorruptible according to Aristotle, Tycho, and others); among bodies of such nobility by the admission of everyone (including Copernicus himself, who declares them to be ordered and arranged in the best possible manner and who removes from them any inconstancy of power); because, I say, of its placing among bodies as pure as Venus and Mars this sink of all corruptible material; that is, the earth, with the water, the air, and all their mixtures!

How much superior a distribution, and how Much more suitable it is to nature--indeed, to God the Architect Himself--to separate the pure from the impure, the mortal from the immortal, as all other schools teach, showing us that impure and infirm materials are confined within the narrow arc of the moon's orbit, above which the celestial objects rise in an unbroken series!

SALV. It is true that the Copernican system creates disturbances in the Anistotelian universe, but we are dealing with our own real and actual universe.

If a disparity in essence between the earth and the heavenly bodies is inferred by this author from the incorruptibility of the latter and the corruptibility of the former in Aristotle's sense, from which disparity he goes on to conclude that motion must exist in the sun and fixed stars, With the earth immovable, then he is wandering about in a paralogism and assuming what is in question. For Aristotle wants to infer the incorruptibility of heavenly bodies from their motion, and it is being debated whether this is theirs or the earth's. Of the folly of this rhetorical deduction, enough has already been said. What is more vapid than to say that the earth and the elements are banished and sequestered from the celestial sphere and confined within the lunar orbit? Is not the lunar orbit one of the celestial spheres, and according to their consensus is it not right in the center of them all? This is indeed a new method of separating the impure and sick from the sound-giving to the infected a place in the heart of the city! I should have thought that the leper house would be removed from there as far as possible.

Copernicus admires the arrangement of the parts of the universe because of God's having placed the great luminary which must give off its mighty splendor to the whole temple right in the center of it, and not off to one side. As to the terrestrial globe being between Venus and Mars, let me say one word about that. You yourself, on behalf of this author, may attempt to remove it, but please let us not entangle these little flowers of rhetoric in the rigors of demonstration. Let us leave them rather to the orators, or better to the poets, who best know how to exalt by their graciousness the most vile and sometimes even pernicious things. Now if there is anything remaining for us to do, let us get on with it.

SIMP. Here is the sixth and last argument, in which he puts it down as an unlikely thing that a corruptible and evanescent body could have a perpetual regular motion. This he supports by the example of the animals, which, though they move with their natural motion, nevertheless get tired and must rest to restore their energy. And what is such motion compared to the motion of the earth, which is immense in comparison with theirs? Yet the earth is made to move in three discordant and distractingly different ways I Who would ever be able to assert such a thing, except someone who was sworn to its defense?

Nor in this case is there any use in Copenicus saying that this motion, because it is natural to the earth and not constrained, works contrary effects to those of forced motions; and that things which are given impetus are destined to disintegrate and cannot long subsist, whereas those made by nature maintain themselves in their optimum arrangement. This reply, I say, is no good; it falls down before our answer.

For the animal is a natural body too, not an artificial one; and its movement is natural, deriving from the soul; that is, from an intrinsic principle, while that motion is constrained whose principle is outside and to which the thing moved contributes nothing. Yet if the animal continues its motion long, it becomes exhausted and would even die if it obstinately tried to force itself on.

You see, therefore, how everywhere in nature traces are to be found which are contrary to the position of Copernicus, and never one in favor of it. And in order that I shall not have to resume the role of this opponent, hear what be has to say against Kepler (with whom he is in disagreement) in regard to what this Kepler has objected against those to whom it seemed an unsuitable or even an impossible thing to expand the stellar sphere as much as the Copernican position requires. Kepler objects to this by saying: *"Difficilius est accidens prueter modulum subiecti intendere, quam subiectum sine accidente augere: Copernicus igitur verisimiliusfacit, qui auget orbem stellarum fixarum absque motu, quam Ptolenweza, qui auget motumfixarum immensa velocilate."* ("It is harder to stretch the property beyond the model of the thing than to augment the thing without the property. Copernicus therefore has more probability on his side, increasing the orb of the stars as fixed without motion, than does Ptolemy who augments the motion of the fixed stars by an immense velocity.") The author resolves this objection, marveling that Kepler was so misled as to say that the Ptolemaic hypothesis increases the motion beyond the model of the subject, for it appears to him that this is increased only in proportion to the model, and that in accordance with this latter the velocity of motion is augmented. He proves this by imagining a millstone which makes one revolution in twenty-four hours, which motion will be called very slow. Next he supposes its radius to be prolonged all the way to the sun; the velocity of its extremity will equal that of the sun; prolonging it to the stellar sphere, it will equal the velocity of the fixed stars. Yet at the circumference of the millstone it will be very slow. Next, applying this reflection about the millstone to the stellar sphere, let us imagine a point on the radius of that sphere as close to its center as the radius of the millstone. Then the same motion which is very rapid in the stellar sphere will be very slow at this point. The size of the body is what makes it become very fast from being very slow, and thus the velocity does not grow beyond the model of the subject, but rather it increases according to that and to its size, very differently from what Kepler thinks.

SALV. I do not believe that this author entertained so poor and low an opinion of Kepler as to be able to persuade himself that Kepler did not understand that the farthest point on a line drawn from the center out to the starry orb moves faster than a point on the same line no more than two yards from the center. Therefore he must have seen and comprehended perfectly well that what Kepler meant was that it was less unsuitable to increase an immovable body to an enormous size than to attribute an excessive velocity to a body already vast, paying attention to the proportionality *(modulo)*--that is to say, to the standard and example--of other natural bodies, in which it is seen that as the distance from the center increases, the velocity is decreased; that is, the period of rotation for them requires a longer time. But in a state of rest, which is incapable of being made greater or less, the size of the body makes no difference whatever. So that if the author's reply Is to have any bearing upon Kepler's argument, this author will have to believe that it is all the same to the motive principle whether a very tiny or an immense body is moved for the same time, the increase of velocity being a direct consequence of the increase in size. But this is contrary to the architectonic rule of nature as observed in the model of the smaller spheres, Just as we see in the planets (and most palpably in the satellites of Jupiter) that the smaller orbs revolve in the shorter times. For this reason Saturn's time of revolution is longer than the period of any lesser orb, being thirty years. Now to pass from this to a much larger sphere, and make that revolve in twenty-four hours, can truly be said to go beyond the rule of the model. So that if we consider the matter carefully, the author's answer does not go against the sense and idea of the argument, but against its expression and manner of speaking. And here also the author is wrong, nor can he deny having in a way perverted the sense of the words in order to charge Kepler with too crass an ignorance. But the imposture is so crude that with all his censure

he has not been able to detract from the impression that Kepler has made upon the minds of the learned with his doctrine.

Then as to the objection against the perpetual motion of the earth, taken from the impossibility of its keeping on without becoming fatigued, since animals themselves that move naturally and from an internal principle get tired and have need of repose to relax their members ...

SAGR. It seems to me that I hear Kepler answering him that there are also animals which refresh themselves from weariness by rolling on the ground, and that hence there is no need to fear that the earth will tire; it may even be reasonably said that it enjoys a perpetual and tranquil repose by keeping itself in an eternal rolling about.

SALV. Sagredo, you are too caustic and sarcastic. Let us put all joking aside, for we are dealing with serious matters.

SAGR. Excuse me, Salviati, but to me what I have just said is not so far from relevant as perhaps you make it out to be. For a movement that serves for repose and removes the weariness from a body tired of traveling may much more easily serve to ward it off, just as preventive remedies are easier than curative ones. And I am sure that if the motion of animals took place as does this one which is attributed to the earth, they would not weary at all. For the fatigue of the animal body proceeds, to my thinking, from the employment of but one part in moving itself and the rest of the body. Thus, for instance, in walking, only the thighs and the legs are used to carry themselves and all the rest, but on the other hand you see the movement of the heart to be indefatigable, because it moves itself alone.

Besides, I don't know how true it is that the movement of animals is natural rather than constrained. Rather, I believe it can be truly said that the soul naturally moves the members of the animal with a preternatural motion. For if motion upward is preternatural to heavy bodies, the raising of such heavy bodies as the thigh and the leg to walk cannot be done without constraint, and therefore not without tiring the mover. Climbing up a ladder carries a heavy body upward against its natural tendency, from which follows weariness because of the natural repugnance of heaviness to such a motion. But if a movable body has a motion to which it has no repugnance whatever, what tiredness or diminution of force and of power need be feared on the part of the mover? And why should power be dissipated where it is not employed at all?

SIMP. It is against the contrary motions by which the terrestrial globe is imagined to move that the author directs his objection.

SAGR. It has already been said that they are not contrary at all, and that in this the author is much deceived, so that the strength of his objection is turned against the objector himself when he will have it that the *primum mobile* carries all the lower spheres along, contrary to the motion which they are continually employing at the same time. Therefore it is the *primum mobile* which ought to get tired, since besides moving itself it has to take along many other spheres which moreover oppose it with a contrary motion. Hence the last conclusion that the author drew, saying that in going over the effects of nature, things favorable to the Aristotelian and Ptolemaic opinion are always found and never any that do not contradict Copernicus, stands in need of careful consideration. It is better to say that if one of these positions is true and the other necessarily false, it is impossible for any reason, experiment, or correct argument to be found to favor the false one, as none of these things can be repugnant to the true position. Therefore a great disparity must exist between the reasons and arguments that are adduced by the one side and by the other for and against these two opinions, the force of which I leave you to judge for yourself, Simplicio.

SALV. Carried away by the nimbleness of your wit, Sagredo, you have taken the words out of my mouth just when I meant to say something in reply to this last argument of the author's; and although you have replied more than adequately, I wish to add anyway what I had more or less in mind.

He puts it down as a very improbable thing that an evanescent and corruptible body such as the earth could move perpetually with a regular motion, especially since we see animals finally exhaust themselves and stand in need of rest. And to him this improbability is increased by this motion being immeasurably greater in companison with that of animals. Now I cannot understand why he should be disturbed at present about the speed of the earth, when that of the stellar sphere, which is so much greater, causes him no more considerable disturbance than does that which he ascribes to the velocity of a millstone performing only one revolution every twentv-four hours. If the velocity of rotation of the earth, by being in accord with the model of the millstone, implies no consequence of greater moment than that does, then the author can quit worrying about the exhaustion of the earth; for not even the most languid and sluggish animal--not even a chameleon, I say--would get exhausted from moving no more than five or six yards every twenty-four hours. But if he means to consider the velocity absolutely, and no longer on the model of this millstone, then inasmuch as the movable body must pass over a very great space in twenty-four hours, he should show himself so much the more reluctant to concede this to the starry sphere, which, with incomparably greater speed than that of the earth, must take along with it thousands of bodies, each much larger than the terrestrial globe.

It would now remain for us to see the proof by which this author concludes that the new stars of 1572 and 1604 were sublunar in position, and not celestial, as the astronomers of that time were commonly persuaded; truly a great undertaking. But since these writings are new to me, and long by reason of so many calculations, I thought that it would be more expeditious for me to look them over as well as I can between this evening and tomorrow morning; and then tomorrow, returning to our accustomed discussions, I shall tell you what I have got out of them. Then, if there is time enough, we shall discuss the annual movement attributed to the earth.

Meanwhile, if there is anything else you want to say--particularly you, Simplicio--about matters pertaining to this diurnal motion which has been so lengthily examined by me, there is yet a little while left to us in which this can be discussed.

SIMP. I have nothing else to say, except that the discussions held today certainly seem to me full of the most acute and ingenious ideas adduced on the Copernican side in support of the earth's motion. But I do not feel entirely persuaded to believe them; for after all, the things which have been said prove nothing except that the reasons for the fixedness of the earth are not necessary reasons. But no demonstration on the opposing side is thereby produced which necessarily convinces one and proves the earth's mobility.

SALV. I have never taken it upon myself, Simplicio, to alter your opinion; much less should I desire to pass a definite judgment on such important litigation. My only intention has been, and will still be in our next debate, to make it evident to you that those who have believed that the very rapid motion every twenty-four hours belongs to the earth alone, and not to the whole universe with only the earth excepted, were not blindly persuaded of the possibility and necessity of this. Rather, they had very well observed, heard, and examined the reasons for the contrary opinion, and did not airily wave them aside. With this same intention, if such is your wish and Sagredo's, we can go on to the consideration of that other movement attributed to the same terrestrial globe, first by Anistarchus of Samos and later by Nicholas Copernicus, which is, as I believe you well know, that it revolves under the zodiac in the space of a year around the sun, which is immovably placed in the center of the zodiac.

SIMP. The question is so great and noble that I shall listen to its discussion with deep interest, expecting to hear everything that can be said upon the subject. Following that, I shall go on by myself at my leisure In the deepest reflections upon what has been heard and what is to be heard. And if I gain nothing else, it will be no small thing to be able to reason upon more solid ground.

SAGR. Then in order not to weary Salviati further, let us put an end to today's discussions, and tomorrow we shall take up the discourse again according to our custom, hoping to hear great new things.

SIMP. I shall leave the book on the new stars, but I am taking back this booklet of theses in order to look over once more what is there written against the annual motion, which will be the subject of tomorrow's discussion.

End of the Second Day

LINK TO FIRST DAY
LINK TO THIRD DAY

Trial of Galileo Homepage

THE THIRD DAY

SAGREDO. I have been impatiently awaiting your arrival, that I might hear the novel views about the annual rotation of this globe of ours. This has made the hours seem very long to me last night and this morning, though I have not passed them idly. On the contrary, I have lain awake most of the night running over in my mind yesterday's arguments and considering the reasons adopted by each side in favor of these two opposing positions--the earlier one of Aristotle and Ptolemy, and this later one of Anistarchus and Copernicus. And truly it seems to me that whichever of these theories happens to be wrong, the arguments in its favor are so plausible that it deserves to he pardoned--so long as we pause at the ones produced by its original weighty authors. Yet because of its antiquity the Peripatetic opinion has had many followers, while the other has had but few, partly because of its difficulty and partly because of its novelty. And among the partisans of the former, especially in modem times, I seem to discern some who introduce very childish, not to say ridiculous, reasons in maintaining the opinion which appears to them to be true.

SALV. The same thing has struck me even more forcibly than you. I have heard such things put forth as I should blush to repeat--not so much to avoid discrediting their authors (whose names could always be withheld) as to refrain from detracting so greatly from the honor of the human race. In the long run my observations have convinced me that some men, reasoning preposterously, first establish some conclusion In their minds which, either because of its being their own or because of their having received it from some person who has their entire confidence, impresses them so deeply that one finds it impossible ever to get it out of their heads. Such arguments in support of their fixed idea as they hit upon themselves or hear set forth by others, no matter how simple and stupid these may be, gain their instant acceptance and applause. On the other hand whatever is brought forward against it, however ingenious and conclusive, they receive with disdain or with hot rage--if indeed it does not make them ill. Beside themselves with passion, some of them would not be backward even about scheming to suppress and silence their adversaries. I have had some experience of this myself.

SAGR. I know; such men do not deduce their conclusion from its premises or establish it by reason, but they accommodate (I should have said discommode and distort) the premises and reasons to a conclusion which for them is already established and nailed down. No good can come of dealing with such people, especially to the extent that their company may be not only unpleasant but dangerous. Therefore let us continue with our good Simplicio, who has long been known to me as a man of great ingenuity and entirely without malice. Besides, he is intimately familiar with the Peripatetic doctrine, and I am sure that whatever he does not think up in support of Aristotle's opinion is not I likely to occur to anybody.

But here, all out of breath, comes the very person who has been wished for so long today. --We were just now maligning you.

SIMP. Please don't scold me; blame Neptune for my long delay. For in this morning's ebb he withdrew the waters in such a manner that the gondola in which I was riding, having entered an unlined canal not far from here, was left high and dry. I had to stay there over an hour awaiting the return of the tide. And while I was there, unable to get out of the boat (which had run aground almost instantly), I fell to observing an event which struck me as quite remarkable. As the water slackened, it might he seen to run very swiftly through various rivulets, the mud being exposed in many places. While I was watching this

effect, I saw this motion along one stretch come to a halt, and without pausing a moment the same water would begin to return, the sea turning from retreat to advance without remaining stationary for an instant. This is an effect which I have never happened to see before in all the time I have frequented Venice.

SAGR. Then you cannot often have happened to be stranded among little trickles. On account of their having scarcely any slope, the sinking or rising of the open sea by merely the thickness of a sheet of paper is enough to make the water flow and return a long distance through such rivulets. On some seacoasts the rising of the sea only a few yards makes the water spill over the plains for many thousands of acres.

SIMP. I know that well enough, but I should think that between the lowest point of the sinking and the first point of the rising, some perceptible interval of rest would be bound to intervene.

SAGR. It will appear so to you when you have in mind walls or pilings, upon which this change takes place vertically. But actually there is no state of rest.

SIMP. It would seem to me that these being two contrary motions, there would have to be some rest midway between them, in agreement with Aristotle's doctrine proving that *in puncto regressus mediat quies.*(note: At the instant of retreat, an interval of calm.)

SAGR. I remember the passage well, and I also recall that when I was studying philosophy I was not convinced by Aristotle's proof Indeed, I have had many experiences to the contrary. I might mention them now, but I do not want to have us wander into any more abysses. We have met here to discuss our subject, if possible, without interrupting it as we have in the past two days.

SIMP. Still it will be good, if not to interrupt it, at least to extend it somewhat. For upon returning home yesterday evening I fell to rereading that booklet of theses, where I found some very convincing proofs against this annual motion which is attributed to the earth. And since I did not trust myself to quote them exactly, I have brought the booklet along with me. (note: This is the pamphlet *De tribus novis stellis quae annis 1572, 1600, 1609 comparuere (1628)* by Scipio Chiaramonti, which Simplicio refenred to on the first day (*cf* p. 14).)

SAGR. You have done well. But if we mean to take up our discussion again in accordance with yesterday's agreement, we must first hear what Salviati has to say about the book on the new stars. Then, without further interruptions, we may examine the annual motion.

Now, Salviati, what have you to say in regard to these stars? Have they really been drawn down from the heavens into these baser regions by virtue of the calculations made by this author whom Simplicio has produced?

SALV. Last night I undertook to study his procedures, and this morning I gave them another glance, wondering whether what I thought I had been reading the night before was really written there, or whether I was the victim of ghosts and fantastic imaginings of the night. To my great regret, I found actually written and printed there that which, for the sake of this philosopher's reputation, I should have wished had not been. It seems impossible to me that he does not realize the vanity of his enterprise, both because it Is so obvious and because I remember having heard our friend the Academician praise him. It also seems to me very hard to believe that out of deference to others he could be persuaded to hold his own reputation in such low esteem as to be induced to publish a work from which nothing but censure could be expected from the learned.

SAGR. You might add that there will be rather less than one in a hundred of these, to offset those who will celebrate and exalt him over all the most learned men who exist now or ever have. A man able to

sustain the Peripatetic inalterability of the heavens against a host of astronomers, and one who, to their greater shame, has done battle against them with their own weapons! And if there are half a dozen to a province who perceive his trivialities, what are they against the innumerable multitude who (being able neither to discover these nor to comprehend them) are taken in by all the shouting, and applaud the more the less they understand? And even the few who do understand scorn to make a reply to such worthless and inconclusive scribbles. With good reason, too; for those who do understand have no need of this, and upon those who do not understand it is wasted effort.

SALV. Silence would indeed be the most appropriate reprimand for their worthlessness, were there not other reasons which practically force one to repudiate them. One reason is that we Italians are making ourselves look like ignoramuses and are a laughingstock for foreigners, especially for those who have broken with our religion; I could show you some very famous ones who joke about our Academician and the many mathematicians in Italy for letting the follies of a certain Lorenzini (note: A criticism leveled by Kepler.) appear in print and be maintained as his views without contradiction. But this also might be overlooked In comparison with another and greater occasion for laughter that might be mentioned, which is the hypocrisy of the learned toward the trifling of opponents of this stripe in matters which they do not understand.

SAGR. I could not ask for a better example of their petulance, or of the unhappy situation of a man like Copernicus, placed under the carping of those who do not understand even the rudiments of the position against which they have declared war.

SALV. You will be no less astonished at their manner of refuting the astronomers who declare the new stars to be above the orbits of the planets, and perhaps among the fixed stars themselves *(nel firmamento)*.

SAGR. But how can you have examined this whole book in such a short time? It is certainly a large volume, and there must be numerous demonstrations in it.

SALV. I stopped after these first refutations of his in which, with twelve demonstrations founded upon the observations of twelve of the astronomers who thought that the new star of 1572 (which appeared in Cassiopeia) was in the firmament, he proves it on the contrary to have been sublunar. To do this he compares, two by two, the meridian altitudes taken by different observers in places of different latitude, proceeding in a manner which you will understand presently. And it seems to me that in examining this first procedure of his I have detected in this author a great inability to prove anything against the astronomers or in favor of the Peripatetic philosophers, and that indeed he only confirms their opinion more conclusively. Therefore I did not want to devote myself with equal patience to the examination of his other methods; having given them a superficial glance, I am positive that the inconclusiveness which pervades his first refutation would exist in the others likewise. And the fact is (as you will soon see) that a very few words suffice to refute this work, although it is built up with so many laborious calculations, as you have perceived.

Therefore you shall hear how I proceeded. The author, I say, in order to attack his adversaries with their own weapons, takes a large number of the observations which they themselves have made, these authors being twelve or thirteen in number. On a part of these he bases his calculations, and he deduces such stars to have been below the moon. Now since I am very fond of proceeding by interrogation, and since the author is not here himself, you, Simplicio, shall reply to the queries I am going to make, and say whatever you believe he would say.

Assuming that we are dealing with the nova of 1572 appearing in Cassiopeia, tell me, Simplicio, whether

you think it might have been in different places at the same time. That is, could it he amidst the elements and also be among the planetary orbits, and in addition be above these among the fixed stars, as well as being infinitely higher?

SIMP. Doubtless one must say that it was located in a single place, at a unique and determinate distance from the earth.

SALV. Then if the observations made by the astronomers were correct, and if the calculations made by this author were not erroneous, both the former and the latter would necessarily have to yield exactly the same distance; isn't that right?

SIMP. So far as I can see it would necessarily be so, nor do I believe that the author would contradict this.

SALV. But if, of many computations, not even two came out in agreement, what would you think of that?

SIMP. I should judge that all were fallacious, either through some fault of the computer or some defect on the part of the observers. At best I might say that a single one, and no more, might be correct; but I should not know which one to choose.

SALV. But would you want to deduce a questionable conclusion and establish it as true, from a false basis? Surely not. Now this author's calculations are such that not one of them agrees with any other; you see, then, bow much faith you can put in them.

SIMP. If that is how matters stand, it is truly a serious defect.

SAGR. I want to help Simplicio and his author out by saying to you, Salviati, that your case would indeed be conclusive if the author had undertaken to find out definitely how far the star was from the earth. But I do not believe that that was his intent; he wished only to show that the star was sublunar. Now if, from the observations mentioned and from all the calculations made on these, the height of the star can always be inferred to have been less than that of the moon, this would suffice the author to convict of the crassest ignorance all those astronomers who, whether they erred in geometry or in arithmetic, could not deduce the true conclusions from their own observations.

SALV. Then I had better turn MY attention to you, Sagredo, since you so cunningly sustain the author's doctrine. And let us see whether I can also persuade Simplicio (although he is unskilled at calculations and proofs) that this author's demonstrations are inconclusive to say the least. Consider first that both he and all the astronomers he is in conflict with agree that the new star had no motion of its own, but merely went around with the diurnal motion of the *primum mobile*. But they disagree about its place, the astronomers putting it in the celestial regions (that is, above the moon) and perhaps among the fixed stars, while he judges it to be near the earth; that is, under the arc of the moon's orbit. And since the site of the new star of which we are speaking was toward the north and at no great distance from the pole, so that for us northerners it never set, it was a simple matter to take its meridian altitudes by means of astronomical instruments--its minimal below the pole as well as its maximal above the pole. By combining these, when the observations were made at different places on the earth and at different distances from the north (that is, at places differing among themselves as to polar elevation), the distance of the star could be reasoned out. For if it was placed in the firmament among the other fixed stars, its meridian altitudes when taken at different elevations of the pole would have to differ among themselves in the same way as did these polar elevations. Thus, for example, if the altitude of the star above the horizon had been thirty degrees when taken at a place where the polar elevation was, say, forty-five degrees, then the altitude of the star ought

to be increased four or five degrees in those more northerly lands in which the pole is four or five degrees higher. But if the distance of the star from the earth was very small in comparison with that of the firmament, then its meridian altitudes should have increased noticeably more than the polar elevations as the pole was approached. From such a greater increase--that is, from the excess of the increase of the star's elevation over the increase of the polar altitude, which is called a difference of parallax--the distance of the star from the center of the earth may be quickly calculated by a clear and certain method.

Now this author takes the observations made by thirteen astronomers at different polar elevations, and comparing a part of these (which he selects) he calculates, by using twelve pairings, that the height of the new star was always below the moon. But he achieves this by expecting such gross ignorance on the part of everyone into whose hands his book might fall that it quite turns my stomach. I can hardly see how the other astronomers contain themselves in silence. Especially Kepler, against whom this author particularly declaims; he would not be one to hold his tongue, unless he considered the matter beneath his notice.

Now for your information I have copied on these pages the conclusions that he deduces from his twelve investigations....

SAGR. This is as if I were watching some unfortunate farmer who, after having all his expected harvest beaten down and destroyed by a tempest, goes about with pallid and downcast face, gathering up such poor gleanings as would not serve to feed a chicken for one day.

SALV. Truly, it was with too scant a store of ammunition that this author rose up against the assailers of the sky's inalterability, and it is with chains too fragile that he has attempted to pull the new star down from Cassiopeia in the highest heavens to these base and elemental regions. Now, since the great difference between the arguments of the astronomers and of this opponent of theirs seems to me to have been very clearly demonstrated, we may as well leave this point and return to our main subject. We shall next consider the annual movement generally attributed to the sun, but then, first by Aristarchus of Samos and later by Copernicus, removed from the sun and transferred to the earth. Against this position I know that Simplicio comes strongly armed, in particular with the sword and buckler of his booklet of theses or mathematical disquisitions. It will be good to commence by producing the objections from this booklet.

SIMP. If you don't mind, I am going to leave those for the last, since they were the most recently discovered.

SALV. Then you had better take up in order, in accordance with our previous procedure, the contrary arguments by Aristotle and the other ancients. I also shall do so, in order that nothing shall be left out or escape careful consideration and examination. Likewise Sagredo, with his quick wit, shall interpose his thoughts as the spirit moves him.

SAGR. I shall do so with my customary lack of tact; and since you have asked for this, you will be obliged to pardon it.

SALV. This favor will oblige me to thank and not to pardon you. But now let Simplicio begin to set forth those objections which restrain him from believing that the earth, like the other planets, may revolve about a fixed center.

SIMP. The first and greatest difficulty is the repugnance and incompatibility between being at the center and being distant from it. For if the terrestrial globe must move in a year around the circumference of a circle--that is, around the zodiac--it is impossible for it at the same time to be in the center of the zodiac. But the earth is at that center, as is proved in many ways by Aristotle, Ptolemy, and others.

SALV. Very well argued. There can be no doubt that anyone who wants to have the earth move along the circumference of a circle must first prove that it is not at the center of that circle. The next thing is for us to see whether the earth is or is not at that center around which I say it turns, and in which you say it is situated. And prior to this, it is necessary that we declare ourselves as to whether or not you and I have the same concept of this center. Therefore tell me what and where this center is that you mean.

SIMP. I mean by "center," that of the universe; that of the world; that of the stellar sphere; that of the heavens.

SALV. I might very reasonably dispute whether there is in nature such a center, seeing that neither you nor anyone else has so far proved whether the universe is finite and has a shape, or whether it is infinite and unbounded. Still, conceding to you for the moment that it is finite and of bounded spherical shape, and therefore has its center, it remains to be seen how credible it is that the earth rather than some other body is to be found at that center.

SIMP. Arislotle gives a hundred proofs that the universe is finite, bounded, and spherical.

SALV. Which are later all reduced to one, and that one to none at all. For if I deny him his assumption that the universe is movable all his' proofs fall to the ground, since he proves it to be finite and bounded only if the universe is movable. But in order not to multiply our disputes, I shall concede to you for the time being that the universe is finite, spherical, and has a center. And since such a shape and center are deduced from mobility, it will be the more reasonable for us to proceed from this same circular motion of world bodies to a detailed investigation of the proper position of the center. Even Aristotle himself reasoned about and decided this in the same way, making that point the center of the universe about which all the celestial spheres revolve, and at which he believed the terrestrial globe to be situated. Now tell me, Simplicio: if Aristotle had found himself forced by the most palpable experiences to rearrange in part this order and disposition of the universe, and to confess himself to have been mistaken about one of these two propositions--that is, mistaken either about putting the earth in the center, or about saying that the celestial spheres move around such a center--which of these admissions do you think that he would choose?

SIMP. I think that if that should happen, the Peripatetics ...

SALV. I am not asking the Peripatetics, I am asking Aristotle himself As for the former, I know very well what they would reply. They, as most reverent and most humble slaves of Aristotle, would deny all the experiences and observations in the world, and would even refuse to look at them in order not to have to admit them, and they would say that the universe remains just as Aristotle has written; not as nature would have it. For take away the prop of his authority, and with what would you have them appear in the field? So now tell me what you think Aristotle himself would do.

SIMP. Really, I cannot make up my mind which of these two difficulties he would have regarded as the lesser.

SALV. Please, do not apply this term "difficulty" to something that may necessarily be so, wishing to put the earth in the center of the celestial revolutions was a "difficulty." But since you do not know to which side he would have leaned, and considering him as I do a man of brilliant intellect, let us set about examining which of the two choices is the more reasonable, and let us take that as the one which Aristotle would have embraced. So, resuming our, reasoning once more from the beginning, let us assume out of respect for Aristotle that the universe (of the magnitude of which we have no sensible information beyond

the fixed stars), like anything that is spherical in shape and moves circularly, has necessarily a center for its shape and for its motion. Being certain, moreover, that within the stellar sphere there are many orbs one inside another, with their stars which also move circularly, our question is this: Which is it more reasonable to believe and to say; that these included orbs move around the same center as the universe does, or around some other one which is removed from that? Now you, Simplicio, say what you think about this matter.

SIMP. If we could stop with this one assumption and were sure of not running into something else that would disturb us, I should think it would be much more reasonable to say that the container and the things it contained all moved around one common center rather than different ones.

SALV. Now if it is true that the center of the universe is that point around which all the orbs and world bodies (that is, the planets) move, it is quite certain that not the earth, but the sun, is to be found at the center of the universe. Hence, as for this first general conception, the central place is the sun's, and the earth is to be found as far away from the center as it is from the sun.

SIMP. How do you deduce that it is not the earth, but the sun, which is at the center of the revolutions of the planets?

SALV. This is deduced from most obvious and therefore most powerfully convincing observations. The most palpable of these, which excludes the earth from the center and places the sun here, is that we find all the planets closer to the earth at one time and farther from it at another. The differences are so great that Venus, for example, is six times as distant from us at its farthest as at its closest, and Mars soars nearly eight times as high in the one state as in the other. You may thus see whether Aristotle was not some trifle deceived in believing that they were always equally distant from us.

SIMP. But what are the signs that they move around the sun?

SALV. This is reasoned out from finding the three outer planets--Mars, Jupiter, and Saturn--always quite close to the earth when they are in opposition to the sun, and very distant when they are in conjunction with it. This approach and recession is of such moment that Mars when close looks sixty times as large as when it is most distant. Next, it is certain that Venus and Mercury must revolve around the sun, because of their never moving far away from it, and because of their being seen now beyond it and now on this side of it, as Venus's changes of shape conclusively prove. (note: Venus has phases like the moon.) As to the moon, it is true that this can never separate from the earth in any way, for reasons that will be set forth more specifically as we proceed.

SAGR. I have hopes of hearing still more remarkable things arising from this annual motion of the earth than were those which depended upon its diurnal rotation.

SALV. You will not be disappointed, for as to the action of the diurnal motion upon celestial bodies, it was not and could not be anything different from what would appear if the universe were to rush speedily in the opposite direction. But this annual motion, mixing with the individual motions of all the planets, produces a great many oddities which in the past have baffled all the greatest men in the world.

Now returning to these first general conceptions, I repeat that the center of the celestial rotation for the five planets, Saturn, Jupiter, Mars, Venus, and Mercury, is the sun; this will hold for the earth too, if we are successful in placing that in the heavens. Then as to the moon, it has a circular motion around the earth, from which as I have already said it cannot be separated; but this does not keep it from going around the sun along with the earth in its annual movement.

SIMP. I am not yet convinced of this arrangement at all. Perhaps I should understand it better from the drawing of a diagram, which might make it easier to discuss.

SALV. That shall be done. But for your greater satisfaction and your astonishment, too, I want you to draw it yourself You will see that however firmly you may believe yourself not to understand it, you do so perfectly, and just by answering my questions you will describe it exactly. So take a sheet of paper and the compasses; let this page be the enormous expanse of the universe, in which you have to distribute and arrange its parts as reason shall direct you. And first, since you are sure without my telling you that the earth is located in this universe, mark some point at your pleasure where you intend this to be located, and designate it by means of some letter.

SIMP. Let this be the place of the terrestrial globe, marked A.

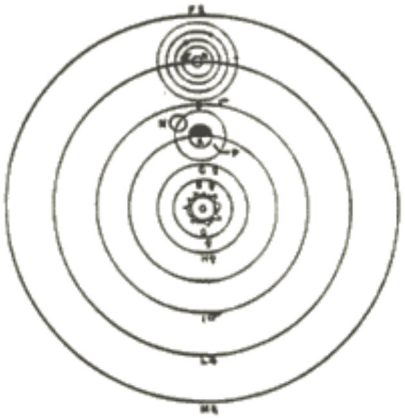

Figure 4

SALV. Very well. I know in the second place that you are aware that this earth is not inside the body of the sun, nor even contiguous to it, but is distant from it by a certain space. Therefore assign to the sun some other place of your choosing, as far from the earth as you like, and designate that also.

SIMP. Here I have done it; let this be the sun's position, marked 0.

SALV. These two established, I want you to think about placing Venus in such a way that its position and movement can conform to what sensible experience shows us about it. Hence you must call to mind, either from past discussions or from your own observations, what you know happens with this star. Then assign it whatever place seems suitable for it to you.

SIMP. I shall assume that those appearances are correct which you have related and which I have read also in the booklet of theses; that is, that this star never recedes from the sun beyond a certain definite interval of forty degrees or so; hence it not only never reaches opposition to the sun, but not even quadrature, nor so much as a sextile aspect. (note: i.e. 180° 90° and 60°.) Moreover, I shall assume that it displays itself to us about forty times as large at one time than at another, greater when, being retrograde, It is approaching evening conjunction with the sun, and very small when it is moving forward toward morning conjunction, and furthermore that when it appears very large, it reveals itself in a homed shape, and when it looks very small it appears perfectly round.

These appearances being correct, I say, I do not see how to escape affirming that this star revolves in a

circle around the sun, in such a way that this circle cannot possibly be said to embrace and contain within itself the earth, nor to be beneath the sun (that is, between the sun and the earth), nor yet beyond the sun. Such a circle cannot embrace the earth because then Venus would sometimes be in opposition to the sun; it cannot be beneath the sun, for then Venus would appear sickle-shaped at both conjunctions; and it cannot be beyond the sun, since then it would always look round and never homed. Therefore for its lodging I shall draw the circle CH around the sun, without having this include the earth.

SALV. Venus provided for, it is fitting to consider Mercury, which, as you know, keeping itself always around the sun, recedes therefrom much less than Venus. Therefore consider what place you should assign to it.

SIMP. There is no doubt that, imitating Venus as it does, the most appropriate place for it will be a smaller circle, within this one of Venus and also described about the sun. A reason for this, and especially for its proximity to the sun, is the vividness of Mercury's splendor surpassing that of Venus and all the other planets. Hence on this basis we may draw its circle here and mark it with the letters BG.

SALV. Next, where shall we put Mars?

SIMP. Mars, since it does come into opposition with the sun, must embrace the earth with its circle. And I see that it must also embrace the sun; for, coming into conjunction with the sun, if it did not pass beyond it but fell short of it, it would appear homed as Venus and the moon do. But it always looks round; therefore its circle must include the sun as well as the earth. And since I remember your having said that when it is in opposition to the sun it looks sixty times as large as when in conjunction, it seems to me that this phenomenon will be well provided for by a circle around the sun embracing the earth, which I draw here and mark DI. When Mars is at the point D, it is very near the earth and in opposition to the sun, but when it is at the point 1, it is in conjunction with the sun and very distant from the earth.

And since the same appearances are observed with regard to Jupiter and Saturn (although with less variation in Jupiter than in Mars, and With still less in Saturn than in Jupiter), it seems clear to me that we can also accommodate these two planets very neatly with two circles, still around the sun. This first one, for Jupiter, I mark EL; the other, higher, for Saturn, is called FM.

SALV. So far you have comported yourself uncommonly well. And since, as you see, the approach and recession of the three outer planets is measured by double the distance between the earth and the sun, this makes a greater variation in Mars than in Jupiter because the circle DI of Mars is smaller than the circle EL of Jupiter. Similarly, EL here is smaller than the circle FM of Saturn, so the variation is still less in Saturn than in Jupiter, and this corresponds exactly to the appearances. It now remains for you to think about a place for the moon.

SIMP. Following the same method (which seems to me very convincing), since we see the moon come into conjunction and opposition with the sun, it must be admitted that its circle embraces the earth. But it must not embrace the sun also, or else when it was in conjunction it would not look homed but always round and full of light. Besides, it would never cause an eclipse of the sun for us, as it frequently does, by getting in between us and the sun. Thus one must assign to it a circle around the earth, which shall be this one, NP, in such a way that when at P it appears to us here on the earth A as in conjunction with the sun, which sometimes it will eclipse in this position. Placed at N, it is seen in opposition to the sun, and in that position it may fall under the earth's shadow and be eclipsed.

SALV. Now what shall we do, Simplicio, with the fixed stars? Do we want to sprinkle them through the immense abyss of the universe, at various distances from any predetermined point, or place them on a

spherical surface extending around a center of their own so that each of them will be the same distance from that center?

SIMP. I had rather take a middle course, and assign to them an orb described around a definite center and included between two spherical surfaces--a very distant concave one, and another closer and convex, between which are placed at vanious altitudes the innumerable host of stars. This might be called the universal sphere, containing within it the spheres of the planets which we have already designated.

SALV. Well, Simplicio, what we have been doing all this while is arranging the world bodies according to the Copernican distribution, and this has now been done by your own hand. Moreover you have assigned their proper movements to them all except the sun, the earth, and the stellar sphere. To Mercury and Venus you have attributed a circular motion around the sun without embracing the earth. Around the same sun you have caused the three outer planets, Mars, Jupiter, and Saturn, to move, embracing the earth within their circles. Next, the moon cannot move in any way except around the earth and without embracing the sun. And in all these movements you likewise agree with Copernicus himself It now remains to apportion three things among the sun, the earth, and the stellar sphere: the state of rest which appears to belong to the earth; the annual motion through the zodiac, which appears to belong to the sun; and the diurnal movement, which appears to belong to the stellar sphere, with all the rest of the universe sharing in it except the earth. And since it is true that all the planetary orbs (I mean Mercury, Venus, Mars, Jupiter, and Saturn) move around the sun as a center, it seems most reasonable for the state of rest to belong to the sun rather than to the earth--just as it does for the center of any movable sphere to remain fixed, rather than some other point of it remote from the center.

Next as to the earth, which is placed in the midst of moving object--I mean between Venus and Mars, one of which makes its revolution in nine months and the other in two years--a motion requiring one year may be attributed to it much more elegantly than a state of rest, leaving the latter for the sun. And such being the case, it necessarily follows that the diurnal motion, too, belongs to the earth. For if the sun stood still, and the earth did not revolve upon itself but merely had the annual movement around the sun, our year would consist of no more than one day and one night; that is, six months of day and six months of night, as was remarked once previously.

See, then, how neatly the precipitous motion of each twenty-four hours is taken away from the universe, and how the fixed stars (which are so many suns) agree with OUT sun in enjoying perpetual rest. See also what great simplicity is to be found in this rough sketch, yielding the reasons for so many weighty phenomena in the heavenly bodies.

SAGR. I see this very well indeed. But just as you deduce from this simplicity a large probability of truth in this system, others may on the contrary make the opposite deduction from it. If this very ancient arrangement of the Pythagoreans is so well accommodated to the appearances, they may ask (and not unreasonably) why it has found so few followers in the course of centuries; why it has been refuted by Aristotle himself, and why even Copernicus is not having any better luck with it in these latter days.

SALV. Sagredo, if you had suffered even a few times, as I have so often, from hearing the sort of follies that are designed to make the common people contumacious and unwilling to listen to this innovation (let alone assent to it), then I think your astonishment at finding so few men holding this opinion would dwindle a good deal. It seems to me that we can have little regard for imbeciles who take it as a conclusive proof in confirmation of the earth's motionlessness, holding them firmly in this belief, when they observe that they cannot dine today at Constantinople and sup in Japan, or for those who are positive that the earth is too heavy to climb up over the sun and then fall headlong back down again. There is no need to bother about such men as these, whose name is legion, or to take notice of their fooleries. Neither

need we try to convert men who define by generalizing and cannot make room for distinctions, just in order to have such fellows for our company in very subtle and delicate doctrines. Besides, with all the proofs in the world what would you expect to accomplish in the minds of people who are too stupid to recognize their own limitations?

No, Sagredo, my surprise is very different from yours. You wonder that there are so few followers of the Pythagorean opinion, whereas I am astonished that there have been any up to this day who have embraced and followed it. Nor can I ever sufficiently admire the outstanding acumen of those who have taken hold of this opinion and accepted it as true; they have through sheer force of intellect done such violence to their own senses as to prefer what reason told them over that which sensible experience plainly showed them to the contrarv. For the arguments against the whirling of the earth which we have already examined are very plausible, as we have seen; and the fact that the Ptolemiacs and Aristotelians and all their disciples took them to be conclusive is indeed a strong argument of their effectiveness. But the experiences which overtly contradict the annual movement are Indeed so much greater in their apparent force that, I repeat, there is no limit to my astonishment when I reflect that Aristarchus and Copernicus were able to make reason so conquer sense that, in defiance of the latter, the former became mistress of their belief

SAGR. Then we are about to encounter still further strong attacks against this annual movement?

SALV. We are, and such obvious and sensible ones that were it not for the existence of a superior and better sense than natural and common sense to join forces with reason, I much question whether 1, too, should not have been much more recalcitrant toward the Copemican system than I have been since a clearer light than usual has illuminated me.

SAGR. Well, then, Salviati, let us get down to cases, as they say; for every word spent otherwise seems to me to be wasted.

SALV. I am at your service ...

SIMP. Gentlemen, please give me a chance to restore harmony to my mind, which I now find very much upset by certain matters which Salviati has just touched upon. Then, when this storm has subsided, I shall be able to listen to your theories more profitably. For there is no use forming an image in a wavy mirror, as the Latin poet has told us so graciously by writing:

... nuper me in lillore vidi,
Cum placidum ventis staret mare.

["Upon the shore I lately viewed myself, When the sea stood still, unruffled by the winds." (Virgil, Bucolics 2.25)]

SALV. You are quite right; tell us your difficulties.

SIMP. Those who deny the diurnal motion to the earth because they do not see themselves being transported to Persia or Japan have been called by you just as dull-witted as those who oppose the annual motion because of the repugnance they feel against admitting that the vast and ponderous bulk of the terrestrial globe can raise itself on high and then descend to the depths, as it would have to do if it revolved about the sun annually. Now I, without blushing to be numbered among such simpletons, feel in my own mind this very repugnance as to the second point against the annual motion, the more so when I see how much resistance is made to motion even over a plain by, I shall not say a mountain, but a mere stone; and even the former would be but the tiniest fraction of an Alpine range. Therefore I beg you not to

scorn such objections entirely, but to solve them; and not for me alone, but also for others to whom they seem quite real. For I think it is very difficult for some people, simple though they may be, to recognize and admit that they are simple just because they know themselves to be so regarded.

SAGR. Indeed, the simpler they are, the more nearly impossible it will be to convince them of their own shortcomings. And on this account I think that it is good to resolve this and all similar objections, not only that Simplicio should be satisfied, but also for other reasons no less important. For it is clear that there are plenty of people who are well versed in philosophy and. the other sciences but who, either through lack of astronomy or mathematics or some other discipline which would sharpen their minds for the penetration of truth, adhere to silly doctrines like these. That is why the situation of poor Copernicus seems to me lamentable; he could expect only censure for his views and could not let them fall into the hands of anyone who, being unable to comprehend his arguments (which are very subtle and therefore difficult to master), would be convinced of their falsity on account of some superficial appearances, and would go about declaring them to be wrong and full of error. If people cannot be convinced by the arguments, which are quite abstruse, it is good to make sure that they recognize the vapidity of these objections. From such knowledge comes moderation in their judgement and condemnation of the doctrine which at present they consider erroneous. Accordingly I shall raise two other objections against the diurnal motion, which not so long ago were to be heard put forward by important men of letters, and after that we shall look into the annual motion.

The first was that if it were true that the sun and other stars did not rise over the eastern horizon, but the eastern side of the earth sank beneath them while they remained motionless, then it would follow that after a short time the mountains, sinking downward with the rotation of the terrestrial globe, would get into such a position that whereas a little earlier one would have had to climb steeply to their peaks, a few hours later one would have to stoop and descend in order to get there.

The other was that if the diurnal motion belonged to the earth, it would have to be so rapid that anyone placed at the bottom of a well would not for a moment be able to see a star which was directly above him, being able to see it only during the very brief instant in which the earth traverses two or three yards, this being the width of the well. Yet experiment shows that the apparent passage of such a star in going over the well takes quite a while--a necessary argument that the mouth of the well does not move with that rapidity which is required for the diurnal movement. Hence the earth is motionless.

SIMP. Of these two arguments, the second really does seem persuasive to me; but as to the first, I think I could clear that up myself. For I consider it the same thing for the terrestrial globe to move about its own center and carry a mountain eastward with it, as for the globe to stand still while the mountain was detached at the base and drawn along the earth. And I do not see that carrying the mountain over the earth's surface is an operation any different from sailing a ship over the surface of the sea. So if the objection of the mountain were valid, it would follow I ikeW`1'se that as the ship continued its voyage and became several degrees distant from our ports, we should have to climb its mast not merely in order to ascend, but to move about in a plane, or eventually even to descend. Now this does not happen, nor have I ever heard of any sailor, even among those who have circumnavigated the globe, who had found any difference in such actions (or any others performed on board ship) because of the ship being in one place rather than another.

SALV. You argue very well, and if it had ever entered the mind of the author of this objection to consider how this neighoring eastern mountain of his would, if the terrestrial globe revolved, be found in a couple of hours to have been carried by that motion to where Mt. Olympus, for example, or Mt. Carmel is now located, he would have seen that by his own line of reasoning he would be obliged to believe and admit that in order to get to the top of the latter mountains one would in fact have to descend. Such people have

the same kind of mind as do those who deny the antipodes on the grounds that one cannot walk with his head down and his feet attached to the ceiling; they produce ideas that are true and that they completely understand, but they do not find it easy to deduce the simplest solutions for their difficulties. I mean, they understand very well that to gravitate or to descend is to approach the center of the terrestrial globe, and that to ascend is to depart from that; but they fail to understand that our antipodes have no trouble at all in sustaining themselves or in walking because they are just like us, having the soles of their feet toward the center of the earth and their heads toward the sky.

SAGR. Yet we know that men who are profoundly ingenious in other fields are blind to such ideas. This confirms what I have just said; it is good to remove every objection, even the feeblest. Therefore the matter of the well should also be answered.

SALV. This second argument does indeed have some elusive appearance of cogency. Nevertheless, I think it certain that if one were to interrogate the very person to whom it occurs, to the end that he might express himself better by explaining just what results ought to follow if one assumes the diurnal rotation of the earth, but which appear to him not to take place; then, I say, I believe that he would get all tangled up in explaining this question and its consequences--perhaps no less than he would disentangle it by thinking it over.

SIMP. To be perfectly frank, I am sure that that is what would happen, although I too find myself right now in this same confusion. For at first glance it seems to me that the argument is binding, but on the other hand I am beginning to realize that other troubles would arise if the reasoning were to continue along the same line For this extremely rapid Course, which ought to be perceived in the star if the motion belonged to the earth, should also be discovered in it if the motion were its own--even more so, since it would have to be thousands of times as fast in the star as in the earth. On the other hand, the star must be lost to sight by passing the mouth of the well, which would be only a couple of yards in diameter, if the well goes along with the earth more than two million yards per hour. Indeed, this seems to be such a transitory glimpse that one cannot even imagine it; yet from the bottom of a well a star is seen for quite a long time. So I should like to be put in the clear about this matter.

SALV. Now I am strongly confirmed in my belief about the confusion of the author of this objection, seeing that you too, Simplicio, becloud what you mean and do not really grasp what you should be saying. I deduce this principally from your omitting a distinction which is a principal point in this matter. So tell me whether in carrying out this experiment (I mean this one of the star passing over the mouth of the well) you would make any distinction between the well being deeper or shallower; that is, between the observer being farther from or closer to its mouth. For I have not heard you make any mention of this.

SIMP. The fact is that I had not thought about it, but your question has awakened my mind to it, and hints to me that such a distinction must be quite necessary. Already I begin to see that in order to determine the time of the passage, the depth of the well may perhaps make no less difference than its width.

SALV. Still, I rather question whether the width makes any difference to us, or very much.

SIMP. Why, it seems to me that having to travel 10 yards of breadth takes ten times as long as to pass I yard. I am sure that a boat 10 yards long will pass beyond my view long before a galley 100 yards long will do so.

SALV. So, we still persist in that inveterate idea of not moving unless our legs carry us.

What you are saying is true, my dear Simplicio, if the object you see is in motion while you remain

stationary to observe it. But if you are in a well when the well and you together are carried along by the rotation of the earth, don't you see that not in an hour, nor in a thousand, nor in all eternity will you ever be overtaken by the mouth of the well? The manner in which the moving or nonmoving of the earth acts upon you in such a situation can be recognized not from the mouth of the well, but from some other separate object not sharing the same state of motion--or I should say, of rest.

SIMP. So far so good; but assume that I, being in the well, am carried together with it by the diurnal motion, and that the star seen by me is motionless. The opening of the well (which alone allows my sight to pass beyond) being not more than three yards, out of so many millions of yards in the balance of the terrestrial surface which are hindering my view, how can the time of my seeing be a perceptible fraction of that of my not seeing?

SALV. You are still falling into the same quibble, and in fact you will need someone to help you out of it. It is not the width of the well, Simplicio, which measures the time of visibility of the star, since in that case you would see it perpetually, as the well would give passage to your vision perpetually. No, the measure of this time must be obtained from that fraction of the motionless heavens which remains visible through the opening of the well.

SIMP. Is not that part of the sky which I perceive the same fraction of the entire heavenly sphere as the mouth of the well is of the terrestrial sphere?

SALV. I want you to answer that for yourself. Tell me whether the mouth of the well is always the same fraction of the earth's surface.

SIMP. There is no doubt that it is always the same.

SALV. And how about the part of the sky which is seen by the person in the well? Is that always the same fraction of the whole celestial sphere?

SIMP. Now I am beginning to sweep the darkness from my mind, and to understand what you hinted to me a little while ago--that the depth of the well has something to do with this matter. For I do not question that the more distant the eye is from the mouth of the well, the smaller Will be the part of the sky which it Will perceive, and consequently the sooner this will have been passed and become lost to view by whoever is looking at it from the bottom of the well.

SALV. But is there any place in the well from which he would perceive exactly that fraction of the celestial sphere which the mouth of the well is of the earth's surface?

SIMP. It seems to me that if the well were excavated to the center of the earth, perhaps from there one might see a part of the sky which would be to it as the well is to the earth. But leaving the center and rising toward the surface, an ever larger part of the sky would be revealed.

SALV. And finally, placing the eye at the mouth of the well, it would perceive one-half the sky, or very little less, which would take twelve hours in passing, assuming that we were at the equator. A while ago I sketched for you an outline of the Copernican system, against the truth of which the planet Mars launches a ferocious attack. For If it were true that the distances of Mars from the earth varied as much from minimum to maximum as twice the distance from the earth to the sun, then when it is closest to us its disc would have to look sixty times as large as when it is most distant. Yet no such difference is to be seen. Rather, when it is in opposition to the sun and close to us, it shows itself as only four or five times as large as when, at conjunction, it becomes hidden behind the rays of the sun.

Another and greater difficulty is made for us by Venus, which, if it circulates around the sun as Copernicus says, would be now beyond it and now on this side of it, receding from and approaching toward us by as much as the diameter of the circle it describes. Then when it is beneath the sun and very close to us, its disc ought to appear to us a little less than forty times as large as when it is beyond the sun and near conjunction. Yet the difference is almost imperceptible.

Add to these another difficulty; for if the body of Venus is intrinsically dark, and like the moon it shines only by illumination from the sun, which seems reasonable, then it ought to appear homed when it is beneath the sun, as the moon does when it is likewise near the sun--a phenomenon which does not make itself evident in Venus. For that reason, Copernicus declared that Venus was either luminous in itself or that its substance was such that it could drink in the solar light and transmit this through its entire thickness in order that it might look resplendent to us. In this manner Copernicus pardoned Venus its unchanging shape, but he said nothing about its small variation in size; much less of the requirements of Mars. I believe this was because he was unable to rescue to his own satisfaction an appearance so contradictory to his view, yet being persuaded by so many other reasons, he maintained that view and held it to be true.

Besides these things, to have all the planets move around together with the earth, the sun being the center of their rotations, then the moon alone disturbing this order and having its own motion around the earth (going around the sun in a year together with the earth and the whole elemental sphere) seems in some way to upset the whole order and to render it improbable and false.

These are the difficulties which make me wonder at Aristarchus and Copernicus. They could not have helped noticing them, without having been able to resolve them; nevertheless they were confident of that which reason told them must be so in the light of many other remarkable observations. Thus they confidently affirmed that the structure of the universe could have no other form than that which they had described. Then there are other very serious but beautiful problems which are not easy for ordinary minds to resolve, but which were seen through and explained by Copernicus; these we shall put off until we have answered the objections of people who show themselves hostile to this position.

Coming now to the explanations and replies to the three grave objections mentioned, I say that the first two are not only not contrary to the Copernican system, but that they absolutely favor it, and greatly. For both Mars and Venus do show themselves variable in the assigned proportions, and Venus does appear homed when beneath the sun, and changes her shape in exactly the same way as the moon.

SAGR. But if this was concealed from Copemicus, how is it revealed to you?

SALV. These things can be comprehended only through the sense of sight, which nature has not granted so perfect to men that they can succeed in discerning such distinctions. Rather, the very instrument of seeing introduces a hindrance of its own. But in our time it has pleased God to concede to human ingenuity an invention so wonderful as to have the power of increasing vision four, six, ten, twenty, thirty, and forty times, and an infinite number of objects which were invisible, either because of distance or extreme minuteness, have become visible by means of the telescope.

SAGR. But Venus and Mars are not objects which are invisible because of any distance Or small size. We perceive these by simple natural vision. Why, then, do we not discern the differences in their sizes and shapes?

SALV. In this the impediment of our eyes plays a large part, as I have just hinted to you. On account of

that, bright distant objects are not represented to us as simple and plain, but are festooned with adventitious and alien rays which are so long and dense that the bare bodies are shown as expanded ten, twenty, a hundred, or a thousand times as much as would appear to us if the little radiant crown which is not theirs were removed.

SAGR. Now I recall having read something of the sort, but I don't remember whether it was in the *Solar Letters* or in *Il Saggiatore* by our friend. (note: Galileo.) It would be a good thing, in order to refresh my memory as well as to inform Simplicio, who perhaps has not read those works, to explain to us in more detail how the matter stands. For I should think that a knowledge of this would be most essential to an understanding of what is now under discussion.

SIMP. Everything that Salviati is presently setting forth is truly new to me. Frankly, I had no interest in reading those books, nor up till now have I put any faith in the newly introduced optical device. Instead, following in the footsteps of other Peripatetic philosophers of my group, I have considered as fallacies and deceptions of the lenses those things which other people have admired as stupendous achievements. If I have been in error, I shall be glad to be lifted out of it; and, charmed by the other new things I have heard from you, I shall listen most attentively to the rest.

SALV. The confidence which men of that stamp have in their own acumen is as unreasonable as the small regard they have for the judgments of others, It is a remarkable thing that they should think themselves better able to judge such an instrument without ever having tested it, than those who have made thousands and thousands of experiments with it and make them every day. But let us forget about such headstrong people, who cannot even be censured without doing them more honor than they deserve.

Getting back to our purpose, I say that shining objects, either because their light is refracted in the moisture that covers the pupil, or because it is reflected from the edges of the eyelids and these reflected rays are diffused over the pupil, or for some other reason, appear to our eyes as if surrounded by new rays. Hence these bodies look much larger than they would if they were seen by us deprived of such irradiations. This enlargement is made in greater and greater proportion as such luminous objects become smaller and smaller, in exactly such a manner as if we were to suppose a growth of shining hair, say four inches long, to be added around a circle four inches in diameter, which would increase its apparent size nine times; but ...

SIMP. I think you meant to say "three times," since four inches added on each side of a circle four inches in diameter would amount to tripling its magnitude and not to enlarging it nine times.

SALV. A little geometry, Simplicio; it is true that the diameter increases three times, but the surface (which is what we are talking about) grows nine times. For the surfaces of circles, Simplicio, are to each other as the squares of their diameters, and a circle four inches in diameter has to another of twelve inches the same ratio which the square of four has to the square of twelve; that is, 16 to 144. Therefore it will be nine times as large, not three. This is for your information, Simplicio.

Now, to continue, if we add this coiffure of four inches to a circle of only two inches in diameter, the diameter of the crown will be ten inches and the ratio of the circle to the bare body will be as 100 to 4 (for such are the squares of 10 and of 2), so the enlargement would be twenty-five times. And finally, the four inches of hair added to a tiny circle of one inch in diameter would enlarge this eighty-one times. Thus the increase is continually made larger and larger proportionately, according as the real objects which are increased become smaller and smaller.

SAGR. The question which gave Simplicio trouble did not really bother me, but there are some other

things about which I desire a clearer explanation. In particular I should like to team the basis upon which you affirm such a growth to be always equal in all Visible objects.

SALV. I have already partly explained by saying that only luminous objects increase; not dark ones. Now I shall add the rest. Of shining objects, those which are brightest in light make the greatest and strongest reflections upon our pupils, thereby showing themselves as much more enlarged than those less bright. And so as not to go on too long about this detail, let us resort to what is shown us by our greatest teacher; this evening, when the sky is well darkened, let us look at Jupiter; we shall see it very radiant and large. Then let us cause our vision to pass through a tube, or even through a tiny opening which we may leave between the palm of our hand and our fingers, clenching the fist and bringing it to the eye; or through a hole made by a fine needle in a card. We shall see the disc of Jupiter deprived of rays and so very small that we shall indeed judge it to be even less than one-sixtieth of what had previously appeared to us to be a great torch when seen with the naked eye. Afterwards, we may look at the Dog Star, a very beautiful star and larger than any other fixed star. To the naked eye it looks to be not much smaller than Jupiter, but upon taking away its headdress in the manner described above, its disc will be seen to be so small that one would judge it to be no more than one-twentieth the size of Jupiter. Indeed, a person lacking perfect vision will be able to find it only with great difficulty, from which it may reasonably be inferred that this star is one which has a great deal more luminosity than Jupiter, and makes larger irradiations.

Next, the irradiations of the sun and of the moon are as nothing because of the size of these bodies, which by themselves take up so much room in our eye as to leave no place for adventitious rays, so that their discs are seen as shorn and bounded.

We may assure ourselves of the same fact by another experiment which I have made many times--assure ourselves, I mean, that the resplendent bodies Of More vivid illumination give out many more rays than those which have only a pale light. I have often seen Jupiter and Venus together, twenty-five or thirty degrees from the sun, the sky being very dark. Venus would appear eight or even ten times as large as Jupiter when looked at with the naked eye. But seen afterward through a telescope, Jupiter's disc would be seen to be actually four or more times as large as Venus. Yet the liveliness of Venus's brilliance was incomparably greater than the pale light of Jupiter, which comes about only because Jupiter is very distant from the sun and from us, while Venus is close to us and to the sun.

These things having been explained, it will not be difficult to understand how it might be that Mars, when in opposition to the sun and therefore seven or more times as close to the earth as when it is near conjunction, looks to us scarcely four or five times as large in the former state as in the latter. Nothing but irradiation is the cause of this. For if we deprive it of the adventitious rays we shall find it enlarged in exactly the proper ratio. And to remove its head of hair from it, the telescope is the unique and supreme means. Enlarging its disc nine hundred or a thousand times, it causes this to be seen bare and bounded like that of the moon, and in the two positions Varying in exactly the proper proportion.

Next in Venus, which at its evening conjunction when it is beneath the sun ought to look almost forty times as large as in Its morning conjunction, and is seen as not even doubled, it happens in addition to the effects of irradiation that it is sickle--shaped, and its horns, besides being very thin, receive the sun's light obliquely and therefore very weakly. So that because it is small and feeble, it makes its irradiations less ample and lively than when it shows itself to us with its entire hemisphere lighted. But the telescope plainly shows us its horns to be as bounded and distinct as those of the moon, and they are seen to belong to a very large circle, in a ratio almost forty times as great as the same disc when it is beyond the sun, toward the end of its morning appearances.

SAGR. Nicholas Copernicus, what a pleasure it would have been for you to see this part of your system

confirmed by so clear an experiment!

SALV. Yes, but how much less would his sublime intellect be celebrated among the learned! For as I said before, we may see that with reason as his guide he resolutely continued to affirm what sensible experience seemed to contradict. I cannot get over my amazement that he was constantly willing to persist in saying that Venus might go around the sun and be more than six times as far from us at one time as at another, and still look always equal, when it should have appeared forty times larger.

SAGR. I believe then that in Jupiter, Saturn, and Mercury one ought also to see differences of size corresponding exactly to their varying distances.

SALV. In the two outer planets I have observed this with precision in almost every one of the past twenty-two years. In Mercury no observations of importance can be made, since it does not allow itself to be seen except at its maximum angles with the sun, in which the inequalities of its distances from the earth are imperceptible. Hence such differences are unobservable, and so are its changes of shape, which must certainly take place as in Venus. But when we do see it, it would necessarily show itself to us in the shape of a semicircle, just as Venus does at its maximum angles, though its disc is so small and its brilliance so lively that the power of the telescope is not sufficient to strip off its hair so that it may appear completely shorn.

It remains for us to remove what would seem to be a great objection to the motion of the earth.. This is that though all the planets turn about the sun, the earth alone Is not solitary like the others, but goes together in the company of the moon and the whole elemental sphere around the sun in one year, while at the same time the moon moves around the earth every month. Here one must once more exclaim over and exalt the admirable perspicacity of Copernicus, and simultaneously regret his misfortune at not being alive in our day. For now Jupiter removes this apparent anomaly of the earth and moon moving conjointly. We see Jupiter, like another earth, going around the sun in twelve years accompanied not by one but by four moons, together with everything that may be contained within the orbits of its four satellites.

SAGR. And what is the reason for your calling the four Jovian planets "moons"?

SALV. That is what they would appear to be to anyone who saw them from Jupiter. For they are dark in themselves, and receive their light from the sun; this is obvious from their being eclipsed when they enter into the cone of Jupiter's shadow. And since only that hemisphere of theirs is illuminated which faces the sun, they always look entirely illuminated to us who are outside their orbits and closer to the sun; but to anyone on Jupiter they would look completely lighted only when they were at the highest points of their circles. In the lowest part--that is, when between Jupiter and the sun--they would appear homed from Jupiter. In a word, they would make for Jovians the same changes of shape which the moon makes for us Terrestrials.

Now you see how admirably these three notes harmonize with the Copernican system, when at first they seemed so discordant with it. From this, Simplicio will be much better able to see with what great probability one may conclude that not the earth, but the sun, is the center of rotation of the planets. And since this amounts to placing the earth among the world bodies which indubitably move about the sun (above Mercury and Venus but beneath Saturn, Jupiter, and Mars), why will it not likewise be probable, or perhaps even necessary, to admit that it also goes around?

SIMP. These events are so large and so conspicuous that it is impossible for Ptolemy and his followers not to have had knowledge of them. And having had, they must also have found a way to give reasons sufficient to account for such sensible appearances; congruous and probable reasons, since they have

been accepted for so long by so many people.

SALV. You argue well, but you must know that the principal activity of pure astronomers is to give reasons just for the appearances of celestial bodies, and to fit to these and to the motions of the stars such a structure and arrangement of circles that the resulting calculated motions correspond with those same appearances. They are not much worried about admitting anomalies which might in fact be troublesome in other respects. Copernicus himself writes, in his first studies, of having rectified astronomical science upon the old Ptolemaic assumptions, and corrected the motions of the planets in such a way that the computations corresponded much better with the appearances, and vice versa. But this was still taking them separately, planet by planet. He goes on to say that when he wanted to put together the whole fabric from all individual constructions, there resulted a monstrous chimera composed of mutually disproportionate members, incompatible as a whole. Thus however well the astronomer might be satisfied merely as a calculator, there was no satisfaction and peace for the astronomer as a scientist. And since he very well understood that although the celestial appearances might be saved by means of assumptions essentially false in nature, it would be very much better if he could derive them from true suppositions, he set himself to inquiring diligently whether any one among the famous men of antiquity had attributed to the universe a different structure from that of Ptolemy's which is commonly accepted. Finding that some of the Pythagoreans had in particular attributed the diurnal rotation to the earth, and others the annual revolution as well, he began to examine under these two new suppositions the appearances and peculiarities of the planetary motions, all of which he had readily at hand. And seeing that the whole then corresponded to its parts with wonderful simplicity, he embraced this new arrangement, and in it he found peace of mind.

SIMP. But what anomalies are there in the Ptolemaic arrangement which are not matched by greater ones in the Copernican?

SALV. The illnesses are in Ptolemy, and the cures for them in Copernicus. First of all, do not all philosophical schools hold it to be a great Impropriety for a body having a natural circular movement to move irregularly with respect to its own center and regularly around another point? Yet Ptolemy's structure is composed of such uneven movements, while in the Copernican system each movement is equable around its own center. With Ptolemy it is necessary to assign to the celestial bodies contrary movements, and make everything move from east to west and at the same time from west to east, whereas with Copernicus all celestial revolutions are in one direction, from west to east. And what are we to say of the apparent movement of a planet, so uneven that it not only goes fast at one time and slow at another, but sometimes stops entirely and even goes backward a long way after doing so? To save these appearances, Ptolemy introduces vast epicycles, adapting them one by one to each planet, with certain rules about incongruous motions--all of which can be done away with by one very simple motion of the earth. Do you not think it extremely absurd, Simplicio, that in Ptolemy's construction where all planets are assigned their own orbits, one above another, it should be necessary to say that Mars, placed above the sun's sphere, often falls so far that it breaks through the sun's orb, descends below this and gets closer to the earth than the body of the sun is, and then a little later soars immeasurably above it? Yet these and other anomalies are cured by a single and simple annual movement of the earth.

SAGR. I should like to arrive at a better understanding of how these stoppings, retrograde motions, and advances, which have always seemed to me highly improbable, come about in the Copernican system.

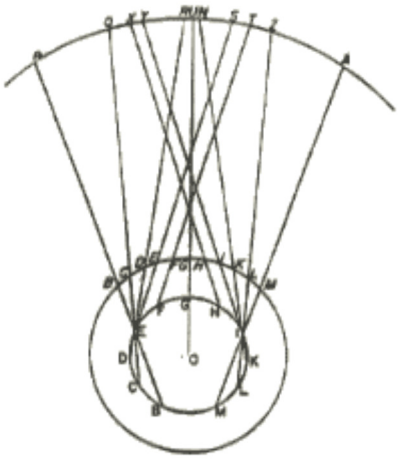

Figure 5

SALV. Sagredo, you will see them come about in such a way that the theory of this alone ought to be enough to gain assent for the rest of the doctrine from anyone who is neither stubborn nor unteachable. I tell you, then, that no change occurs in the movement of Saturn in thirty years, in that of Jupiter in twelve, that of Mars in two, Venus in nine months, or in that of Mercury in about eighty days. The annual movement of the earth alone, between Mars and Venus, causes all the apparent irregularities of the five stars named. For an easy and full understanding of this, I wish to draw you a picture of it. Now suppose the sun to be located in the center 0, around which we shall designate the orbit described by the earth with its annual movement, BGM. The circle described by Jupiter (for example) in 12 years will be *BGM* here, and in the stellar sphere we shall take the circle of the zodiac to be *PUA*. In addition, in the earth's annual orbit we shall take a few equal arcs, BC, CD, DE, EF, FG, GH, H1, IK, KL, and LK and in the circle of Jupiter we shall indicate these other arcs passed over in the same times in which the earth is passing through these. These are *BC, CD, DR, EF, FG, GH, Hf, IK, KL,* and *LM,* which will be proportionately smaller than those noted on the earth's orbit, as the motion of Jupiter through the zodiac is slower than the annual celestial motion.

Now suppose that when the earth is at B, Jupiter is at *B*, then it will appear to us as being in the zodiac at *P*, along the straight line B*BP*. Next let the earth move from B to C and Jupiter from B to C in the same time; to us, Jupiter will appear to have arrived at *Q* in the zodiac, having advanced in the order of the signs from *P* to *Q*. The earth then passing to D and Jupiter to *D*, it will be seen in the zodiac at *R*; and from E, Jupiter being at *E*, it will appear in the zodiac at S, still advancing. But now when the earth begins to get directly between Jupiter and the sun (having arrived at F and Jupiter at *F*), to us Jupiter will appear to be ready to commence returning backward through the zodiac, for during the time in which the earth will have passed through the arc EF, Jupiter will have been slowed down between the points S and T, and will look to us almost stationary. Later the earth coming to G, Jupiter at *G* (in opposition to the sun) will be seen in the zodiac at *U*, turned far back through the whole arc *TU* in the zodiac; but in reality, following always its uniform course, it has advanced not only in its own circle but in the zodiac too, with respect to the center of the zodiac and to the sun which is located there.

The earth and Jupiter then continuing their movements, when the earth is at H and Jupiter is at *H*, It will be seen as having returned far back through the zodiac by the whole arc *UX*; but the earth having arrived at I and Jupiter at *I*, it will apparently have moved in the zodiac by only the small space *XY* and will there appear stationary. Then when the earth shall have progressed to K and Jupiter to *K*, Jupiter will have

advanced through the arc *YN*, in the zodiac; and, continuing its course, from L the earth will see Jupiter at *L* in the point Z Finally, Jupiter at *M* will be seen from the earth at M to have passed to A, still advancing. And its whole apparent retrograde motion in the zodiac will be as much as the arc *TX*, made by Jupiter while it is passing in its own circle through the arc *FH*, the earth going through FH in its orbit.

Now what is said here of Jupiter is to be understood of Saturn and Mars also. In Saturn these retrogressions are somewhat more frequent than in Jupiter, because its motion is slower than Jupiter's, so that the earth overtakes it in a shorter time. In Mars they are rarer, its motion being faster than that of Jupiter, so that the earth spends more time in catching up with it.

Next, as to Venus and Mercury, whose circles are included within that of the earth, stoppings and retrograde motions appear in them also, due not to anv motion that really exists in them, but to the annual motion of the earth. This is acutely demonstrated by Copernicus, enlisting the aid of Apollonius of Perga, in chapter 35 of Book V in his *Revolutions*.

You see, gentlemen, with what ease and simplicity the annual motion--if made by the earth--lends itself to supplying reasons for the apparent anomalies which are observed in the movements of the five planets, Saturn, Jupiter, Mars, Venus, and Mercury. It removes them all and reduces these movements to equable and regular motions; and it was Nicholas Copernicus who first clarified for us the reasons for this marvelous effect.

But another effect, no less wonderful than this, and containing a knot perhaps even more difficult to untie, forces the human intellect to admit this annual rotation and to grant it to our terrestrial globe. This is a new and unprecedented theory touching the sun itself For the sun has shown itself unwilling to stand alone in evading the confirmation of so important a conclusion, and instead wants to be the greatest witness of all to this, beyond exception. So now hear this new and mighty marvel....

...This, Simplicio, is all that occurred to my friend and to myself regarding that which might be adduced in explanation of the appearances in defense of their opinions by the Copernicans and by the Ptolemaics. You may do with it whatever your own judgment persuades you to do.

SIMP. I recognize my own incapacity to take upon myself so important a decision. As to my own ideas, I remain neutral, in the hope that a time Will come when the mind will be freed by an illumination from higher contemplations than these of our human reasoning, and all the mists which keep it darkened will be swept away.

SAGR. Simplicio's counsel is excellent and pious, and worthy of being accepted and followed by everyone, since only that which is derived from the highest wisdom and supreme authority may be embraced with complete security. But so far as human reason is allowed to penetrate, confining myself within the bounds of theory and of probable causes, I shall indeed say (with a little more boldness than Simplicio exhibits) that I have not, among all the many profundities that I have ever heard, met with anything which is more wonderful to my intellect or has more decisively captured my mind (outside of pure geometrical and arithmetical proofs) than these two conjectures, one of which is taken from the stoppings and retrograde motions of the five planets, and the other from the peculiarities of movement of the sunspots. And it appears to me that they yield easily and clearly the true cause of such strange phenomena, showing the reason for such phenomena to be a simple motion which is mixed with many others that are also simple but that differ among themselves. Moreover they show this without introducing any difficulties; rather, they remove all those which accompany other viewpoints. So much so that I am rapidly coming to the conclusion that those who remain hostile toward this doctrine must either not have heard it or must not have understood these arguments, which are so numerous and so conclusive.

SALV. I do not give these arguments the status of either conclusiveness or of inconclusiveness, since (as I have said before) my intention has not been to solve anything about this momentous question, but merely to set forth those physical and astronomical reasons which the two sides can give me to set forth. I leave to others the decision, which ultimately should not be ambiguous, since one of the arrangements must be true and the other false. Hence it is not possible within the bounds of human learning that the reasons adopted by the right side should be anything but clearly conclusive, and those opposed to them, vain and ineffective.

SAGR. Then it is now time for us to hear the other side, from that booklet of theses or disquisitions which Simplicio has brought back with him.

SIMP. Here is the book, and here is the place in which the author first briefly describes the system of the world according to the position of Copernicus, saying: *Terram igitur una cum Luna lotoque hoc elementari Copernicus* etc. ("Therefore the earth, together with the moon and all this elemental world, Copernicus" etc.)

SALV. Wait a bit, Simplicio; for it seems to me that this author at the very outset declares himself to be very ill-informed about the position he undertakes to refute, when he says that Copernicus makes the earth together with the moon trace out the orbis magnnus in a year, moving from east to west; a thing which, as it is false and impossible, has accordingly never been uttered by Copernicus. Indeed, he makes it go in the opposite direction (I mean from west to east; that is, in the ord6r of the signs of the zodiac), so that it appears that the annual motion belongs to the sun, which 'is placed immovably in the center of the zodiac.

You see the excessive boldness of this man's self-confidence, setting himself up to refute another's doctrine while remaining ignorant of the basic foundations upon which the greatest and most important parts of the whole structure are supported. This is a poor beginning for gaining the confidence of the reader, but let us proceed.

SIMP. The system of the universe explained, he begins to propose his objections against the annual movement. The first of these he utters ironically, in derision of Copernicus and his followers, writing that in this fantastic arrangement of the world one must affirm the most sublime inanities: That the sun, Venus, and Mercury are beneath the earth; that heavy material naturally ascends and light stuff descends; that Christ, our Saviour and Redeemer, rose to hell and descended into heaven when He approached the sun. That when Joshua commanded the sun to stand still, the earth stood still--or else the sun moved opposite to the earth; that when the sun is in Cancer, the earth is running through Capricorn, so that the winter signs make the summer and the spring signs the autumn; that the stars do not rise and set for the earth, but the earth for them; and that the east starts in the west while the west begins in the east; in a word, that nearly the whole course of the world is turned inside out.

SALV. All of this is satisfactory to me except his having mixed passages from the ever venerable and mighty Holy Scriptures among these apish puerilities, and his having tried to utilize sacred things for wounding anybody who might, without either affirming or denying anything, philosophize Jokingly and in sport, having made certain assumptions and desiring to argue about them among friends.

SIMP. Truly he scandalized me too, and not a little; especially later, when he adds that if indeed the Copernicans answer these and the like arguments in some distorted way, they still will not be able to answer satisfactorily some things which come later.

SALV. Oh, that is worst of all, for he is pretending to have things which are more effective and convincing than the authority of Holy Writ. But let us, for our part, revere it, and pass on to physical and human arguments. Yet if he does not adduce among his physical arguments matters which make more sense than those set forth up to this point, we may as well abandon him entirely. I am certainly not in favor of wasting words answering such trifling tomfooleries. And as for his saying that the Copernicans do reply to these objections, that is quite false. I cannot believe that any man would put himself to such a pointless waste of time.

SIMP. I, too, concur in this decision, let us, then, listen to his other objections, which are more strongly supported. Now here, as you see, he deduces with very precise calculations that if the orbit in which Copernicus makes the earth travel

Around the sun in a year were scarcely perceptible with respect to the immensity of the stellar sphere, as Copernicus says must be assumed, then one would have to declare and maintain that the fixed stars were at an inconceivable distance from us, and that the smallest of them would be much larger than this whole orbit, while others would be larger than the orbit of Saturn. Yet such bulks are truly too vast, and are incomprehensible and unbelievable.

SALV. I have indeed seen something similar argued against Copernicus by Tycho, so this is not the first time that I have revealed the fallacy--or better, the fallacies--of this argument, built as it is upon completely false hypotheses. It is based upon a dictum of Copernicus which is taken by his adversaries with rigorous literalness, as do those quarrelsome people who, being wrong about the principal issue of the case, seize upon some single word accidentally uttered by their opponents and make a great fuss about it without ever letting up.

For your better comprehension, know that Copernicus first explains the remarkable consequences to the various planets deriving from the annual movement of the earth; in particular the forward and retrograde movements of the three outer planets. Then he adds that these apparent mutations which are perceived to be greater in Mars than in Jupiter, from Jupiter's being more distant, and still less in Saturn, from its being farther away than Jupiter, remain imperceptible in the fixed stars because of their immense distance from us in comparison with the distance of Jupiter or of Saturn. Here the adversaries of this opinion rise up, and take what Copernicus has called "imperceptible" as having been assumed by him to be really and absolutely nonexistent. Remarking that even the smallest of the fixed stars is still perceptible, since it strikes our sense of sight, they set themselves to calculating (with the Introduction of still more false assumptions), and deduce that in Copernicus's doctrine one must admit that a fixed star is much larger than the orbit of the earth.

Now in order to reveal the folly of their entire method, I shall show that by assuming that a star of the sixth magnitude may be no larger than the sun, one may deduce by means of correct demonstrations that the distance of the fixed stars from us is sufficiently great to make quite imperceptible in them the annual movement of the earth which in turn causes such large and observable variations in the planets. Simultaneously I shall clearly expose to you a gigantic fallacy in the assumptions made by the adversaries of Copernicus.

To begin with, I assume along with Copernicus and in agreement with his opponents that the radius of the earth's orbit, which is the distance from the sun to the earth, contains 1,208 of the earth's radii. Secondly, I assume with the same concurrence and in accordance with the truth that the apparent diameter of the sun at its average distance is about one-half a degree, or 300 minutes; this is 1,800 seconds, or 108,000 third-order divisions. And since the apparent diameter of a fixed star of the first magnitude is no more

than 5 seconds, or 300 thirds, and the diameter of one of the sixth magnitude measures 50 thirds (and here is the greatest error of Copernicus's adversaries), then the diameter of the sun contains the diameter of a fixed star of the sixth magnitude 2,160 times. Therefore if one assumes that a fixed star of the sixth magnitude is really equal to the sun and not larger, this amounts to saying that if the sun moved away until its diameter looked to be 1/2160th of what it now appears to be, its distance would have to be 2,160 times what it is In fact now.

This is the same as to say that the distance of a fixed star of the sixth magnitude is 2,160 radii of the earth's orbit. And since the distance from the earth to the sun is commonly granted to contain 1,208 radii of the earth, and the distance of the fixed star is, as we said, 2,160 radii of the orbit, then the radius of the earth in relation to that of its orbit is much greater than (almost double) the radius of that orbit in relation to the stellar sphere. Therefore the difference in aspect of the fixed star caused by the diameter of the earth's orbit would be little more noticeable than that which is observed in the sun due to the radius of the earth. (note: Galileo's numbers are Inaccurate, but serve the purposes of his argument; he seriously underestimated stellar distance, but nevertheless placed the stars well beyond more typical estimations made by those he proceeds to mention.)

SAGR. For a first step, this Is a bad fall.

SALV. It is indeed wrong, since according to this author a star of the sixth magnitude would have to be as large as the earth's orbit in order to justify the dictum of Copernicus. Yet assuming it to be equal only to the sun, which in turn is rather less than one ten-millionth of that orbit, makes the stellar sphere so large and distant that this alone is sufficient to remove this objection against Copernicus.

SAGR. Please make this computation for me.

SALV. The calculation is very short and simple. The diameter of the sun is 11 radii of the earth, and the diameter of the earth's orbit contains 2,416 of these radii, as both parties agree. So the diameter of the orbit contains that of the sun approximately 220 times, and since spheres are to each other as the cubes of their diameters, we take the cube of 220 and we have the orbit 10,648,000 times as large as the sun. The author would say that a star of the sixth magnitude would have to be equal to this orbit.

SAGR. Then their error consists in their having been very much deceived in taking the apparent diameter of the fixed stars.

SALV. That is the error, but not the only one. And truly I am quite surprised at the number of astronomers, and famous ones too, who have been quite mistaken in their determinations of the sizes of the fixed as well as the moving stars, only the two great luminaries being excepted. Among these men are al-Fergani, al-Battani, Thabit ben Korah, and more recently Tycho, Clavius, and all the predecessors of our Academician. For they did not take care of the adventitious irradiation which deceptively makes the stars look a hundred or more times as large as they are when seen without haloes. Nor can these men be excused for their carelessness; it was within their power to see the bare stars at their pleasure, for it suffices to look at them when they first appear in the evening, or just before they vanish at dawn. And Venus, if nothing else, should have warned them of their mistake, being frequently seen in daytime so small that it takes sharp eyesight to see it, though in the following night it appears like a great torch. I Will not believe that they thought the true disc of a torch was as It appears in profound darkness, rather than as it is when perceived in lighted surroundings; for our lights seen from afar at night look large, but from near at hand their true flames are seen to be small and circumscribed. This alone might have sufficed to make them cautious.

To speak quite frankly, I thoroughly believe that none of them--not even Tycho himself, accurate as he

was in handling astronomical instruments and despite his having built such large and accurate ones without a thought for their enormous expense--ever set himself to determine and measure the apparent diameter of any star except the sun and moon. I think that arbitrarily and, so to speak, by rule of thumb some one among the most ancient astronomers stated that such-and-such was the case, and the later ones without any further experiment adhered to what this first one had declared. For if any of them had applied himself to making any test of the matter, he would doubtless have detected the error.

SAGR. But if they lacked the telescope (for you have already said that our friend came to know the truth of the matter by means of that instrument), they ought to be pardoned, not accused of negligence.

SALV. That would be true if they could not have obtained the result without the telescope. It Is true that the telescope, by showing the disc of the star bare and very many times enlarged, renders the operations much easier, but one could carry them on without it, though not with the same accuracy. I have done so, and this is the method I have used. I hung up a light rope in the direction of a star (I made use of Vega, which rises between the north and the northeast) and then by approaching and retreating from this cord placed between me and the star, I found the point where its width just hid the star from me. This done, I found the distance of my eye from the cord, which amounts to the same thing as one of the sides which includes the angle formed at my eye and extending over the breadth of the cord....

SALV. Simplicio, I wish you could for a moment put aside your affection for the followers of your doctrines and tell me frankly whether you believe that they comprehend in their own minds this magnitude which they subsequently decide cannot be ascribed to the universe because of its immensity. I myself believe that they do not. It seems to me that here the situation is just as it is with the grasp of numbers when one gets up into the thousands of millions, and the imagination becomes confused and can form no concept. The same thing happens in comprehending the magnitudes of immense distances; there comes into our reasoning an effect similar to that which occurs to the senses on a serene night, when I look at the stars and judge by sight that their distance is but a few miles, or that the fixed stars are not a bit farther off than Jupiter, Saturn, or even the moon.

But aside from all this, consider those previous disputes between the astronomers and the Peripatetic philosophers about the reasoning as to the distance of the new stars in Cassiopeia and Sagittarius, the astronomers placing these among the fixed stars and the philosophers believing them to be closer than the moon. How powerless are our senses to distinguish large distances from extremely large ones, even when the latter are in fact many thousands of times the larger!

And finally I ask you, O foolish man: Does your imagination first comprehend some magnitude for the universe, which you then judge, to be too vast? If it does, do you like imagining that your comprehension extends beyond the Divine power? Would you like to imagine to yourself things greater than God can accomplish? And if it does not comprehend this, then why do you pass judgment upon things you do not understand?

SIMP. These arguments are very good, and no one denies that the size of the heavens may exceed our imaginings, since God could have created it even thousands of times larger than it is. But must we not admit that nothing has been created in vain, or is idle, in the universe? Now when we see this beautiful order among the planets, they being arranged around the earth at distances commensurate with their producing upon it their effects for our benefit, to what end would there then be interposed between the highest of their orbits (namely, Saturn's), and the stellar sphere, a vast space without anything in it, superfluous, and vain? For the use and convenience of whom?

SALV. It seems to me that we take too much upon ourselves, Simplicio, when we will have it that merely

taking care of us is the adequate work of Divine wisdom and power, and the limit beyond which it creates and disposes of nothing.

I should not like to have us tie its hand so. We should be quite content in the knowledge that God and Nature are so occupied with the government of human affairs that they could not apply themselves more to us even if they had no other cares to attend to than those of the human race alone. I believe that I can explain what I mean by a very appropriate and most noble example, derived from the action of the light of the sun. For when the sun draws up some vapors here, or warms a plant there, it draws these and warms this as if it had nothing else to do. Even in ripening a bunch of grapes, or perhaps just a single grape, it applies itself so effectively that it could not do more even if the goal of all its affairs were just the ripening of this one grape. Now if this grape receives from the sun everything it can receive, and is not deprived of the least thing by the sun simultaneously producing thousands and thousands of other results, then that grape would be guilty of pride or envy if it believed or demanded that the action of the sun's rays should be employed upon itself alone.

I am certain that Divine Providence omits none of the things which look to the government of human affairs, but I cannot bring myself to believe that there may not be other things in the universe dependent upon the infinity of its wisdom, at least so far as my reason informs me; yet if the facts were otherwise, I should not resist believing in reasoning which I had borrowed from a higher understanding. Meanwhile, when I am told that an immense space interposed between the planetary orbits and the starry sphere would be useless and vain, being idle and devoid of stars, and that any immensity going beyond our comprehension would be superfluous for holding the fixed stars, I say that it is brash for our feebleness to attempt to judge the reason for God's actions, and to call everything in the universe vain and superfluous which does not serve us.

SAGR. Say rather, and I think you will be speaking more accurately, "which we do not know to serve us." I believe that one of the greatest pieces of arrogance. or rather madness, that can be thought of is to say, "Since I do not know how Jupiter or Saturn is of service to me, they are superfluous, and even do not exist." Because, O deluded man, neither do I know how my arteries are of service to me, nor my cartilages, spleen, or gall, I should not even know that I had gall, or a spleen, or kidneys, if they had not been shown to me in many dissected corpses. Even then I could understand what my spleen does for me only if it were removed. In order to understand how some celestial body acted upon me (since you want ail their actions to be directed at me), it would be necessary to remove that body for a while, and say that whatever effect I might then feel to be missing in me depended upon that star.

Besides, what does it mean to say that the space between Saturn and the fixed stars, which these men call too vast and useless, is empty of world bodies? That we do not see them, perhaps? Then did the four satellites of Jupiter and the companions of Saturn come into the heavens when we began seeing them, and not before? Were there not innumerable other fixed stars before men began to see them"The nebulae were once only little white patches; have we with our telescopes made them become clusters of many bright and beautiful stars? Oh, the presumptuous, rash ignorance of mankind!

SALV. There is no need, Sagredo, to probe any farther into their fruitless exaggerations. Let us continue our plan, which is to examine the validity of the arguments brought forward by each side without deciding anything, leaving the decision to those who know more about it than we.

Returning to our natural and human reason, I say that these terms "large," "small" "immense," "minute," etc. are not absolute, but relative; the same thing in comparison with various others may be called at one time "immense" and at another "Imperceptible," let alone "small." Such being the case, I ask: In relation to what can the stellar sphere of Copernicus be called too vast? So far as I can see, it cannot be compared

or said to be too vast except in relation to some other thing of the same kind. Now let us take the smallest thing of the same kind, which will be the orbit of the moon. If the stellar orb must be considered too vast in relation to that of the moon, then every other magnitude which exceeds some other of its kind by a similar or greater ratio ought also to be said to be too vast; and likewise, by the same reasoning, it should be said not to exist in the universe. Then the elephant and the whale will be mere chimeras and poetical fictions, because the former are too vast in comparison with ants (being land animals), and the latter in relation to gudgeons (being fish). And if actually found in nature, they would be immeasurably large; for the elephant and whale certainly exceed the ant and gudgeon in a much greater ratio than the stellar sphere does that of the moon, taking the stellar sphere to he as large as is required by the Copernican system.

Besides, how large is the sphere of Jupiter, and how great is that assigned to Saturn as the receptacle of a single star, though the planet itself is small in comparison with a fixed star! Surely if to each fixed star such a large portion of the space in the universe should be assigned as its container, that orb which contains an innumerable quantity of these would have to he made many thousands of times larger than suffices for the needs of Copernicus. Moreover, do you not call a fixed star very small--I mean even one of the most conspicuous ones, let alone those which escape our sight? And we call it so in comparison with the surrounding space. Now if the whole stellar sphere were one single blazing body, who is there that does not understand that in an infinite space there could be assigned a distance so great that, from there, such a brilliant sphere would appear as small as or even smaller than a fixed star now appears to us from the earth? So from such a point we should judge as small the very things which we now call immeasurably huge.

SAGR. To me, a great ineptitude exists on the part of those who would have it that God made the universe more in proportion to the small capacity of their reason than to Ms immense, His infinite, power.

SEMP. All this that you are saying is good, but what the other side objects to is having to grant that a fixed star must be not only equal to, but much greater than, the sun; for both are still individual bodies located within the stellar orb. And it seems to me much to the purpose that this author inquires, "To what end and use are such vast frames? Produced for the earth, perhaps? That is, for a trifling little dot? And why so remote as to appear very small and be absolutely unable to act in any way upon the earth? To what purpose such a disproportionately large abyss between these and Saturn? All these things are baffling, for they cannot be maintained by probable reasons."

SALV. From the questions this fellow asks, it seems to me that one may deduce that if only the sky, the stars, and their distances were permitted to keep the sizes and magnitudes which he has believed in up to this point (though he has surely never imagined for them any comprehensible magnitudes), then he would completely understand and be satisfied about the benefits which would proceed from them to the earth, which itself would no longer be such a trifling thing. Nor would these stars any longer be so remote as to seem quite minute, but large enough to be able to act upon the earth. And the distance between them and Saturn would be in good proportion, and he would have Very probable reasons for everything, which I should very much like to have heard. But seeing how confused and contradictory he is in these few words leads me to believe that he is very thrifty with or else hard up for these probable reasons, and that what he calls reasons are more likely fallacies, even shadows of foolish fantasies. Therefore I ask him whether these celestial bodies really act upon the earth, and whether it was for that purpose that they were made of such-and-such sizes and arranged at such-and-such distances, or whether they have nothing to do with terrestrial affairs? If they have nothing to do with the earth, then it is a great folly for us Terrestrials to want to be arbiters of their sizes and regulators of their local dispositions, we being quite ignorant of all their affairs and interests. But if he says that they do act, and that it is to this end that they are directed,

then this amounts to admitting what he denies in another place, and praising what he has just finished condemning when he said that celestial bodies located at such distances from the earth as to appear minuscule could not act upon it in any way. Now, my good man, in the starry sphere, which is already established at whatever distance it is, and which you have just decided is well proportioned for an influence upon terrestrial matters, a multitude of stars do appear quite small, and a hundred times as many are entirely invisible to us--which is to appear smaller than small. Therefore you must now (contradicting yourself) deny their action upon the earth, or else (still contradicting yourself) admit that their appearing small does not detract from their power to act. Or else (and this would be a frank and honest confession) you must grant and freely admit that your judgment about their sizes and distances was folly, not to say presumption or brashness.

SIMP. As a matter of fact, I also saw immediately, upon reading this passage, the obvious contradiction in his saying that the stars of Copernicus, so to speak, could not act upon the earth because they appeared so small, and his not noticing that he had granted action upon the earth to the stars of Ptolemy and his own, these not merely appearing small but being for the most part invisible.

SALV. But now I come to another point. Upon what basis does he say that the stars appear so smaII? Is it perhaps because that is the way they look to us? Does he not know that this comes about from the instrument which we use in looking at them--that is, our eyes? Or for that matter that by changing instruments we may see them larger and larger, as much as we please? Who knows; perhaps to the earth, which beholds them without eyes, they may appear quite huge and as they really are?

But it is time for us to leave these trifles and get to more important matters. I have already demonstrated two things: first, at what distance the firmament may be placed so that the diameter of the earth's orbit would make no greater variation in it than that which the terrestrial diameter makes with respect to the sun at its distance therefrom, and I then showed that in order to make a fixed star appear to us as of the size we see, it is not necessary to assume it to be larger than the sun. Now I should like to know whether Tycho or any of his disciples has ever tried to investigate in any way whether any phenomenon is perceived in the stellar sphere by which one might boldly affirm or deny the annual motion of the earth.

SAGR. I should answer "no" for them, they having had no need to do so, since Copernicus himself says that there is no such variation there; and they, arguing *ad hominem*, grant this to him. Then on this assumption they show the improbability which follows from it; namely, it would be required to make the sphere so immense that in order for a fixed star to look as large as it does, it would actually have to be so immense in bulk as to exceed the earth's orbit--a thing which is, as they say, entirely unbelievable. SALV. So it seems to me, and I believe that they argue against the man more in the defense of another man than out of any great desire to get at the truth. And not only do I believe that none of them ever applied himself to making such observations, but I am not even sure that any of them knew what variation ought to be produced in the fixed stars by the annual movement of the earth, if the stellar sphere were not at such a distance that any variation in them would vanish on account of its smallness. For to stop short of such researches and fall back upon the mere dictum of Copernicus may suffice to refute the man, but certainly not to clear up the fact.

Now it might be that there is a variation, but that it Is not looked for; or that because of its smallness, or through lack of accurate instruments, it was not known by Copernicus. (note: Stellar parallax will not be detected until 1837.) This would not be the first thing that he failed to know, either for lack of instruments or from some other deficiency. Yet, grounded upon most solid theories, he affirmed what seemed to be contradicted by things he did not understand. For as already said, without a telescope it cannot be comprehended that Mars does increase sixty times and Venus forty times in one position as against another, and their differences appeared to be much less than the true ones. Yet since that time it has

become certain that such variations are, to a hair, Just what the Copernican system required. Hence it would be a good thing to investigate with the greatest possible precision whether one could really observe such a variation as ought to be perceived in the fixed stars, assuming an annual motion of the earth....

SIMP. Really, to be quite frank, I do feel a great repugnance against having to concede the distance of the fixed stars to be so great that the alterations just explained would have to remain entirely imperceptible in them.

SALV. Do not completely despair, Simplicio; perhaps there is yet some way of tempering your difficulties. First of all, that the apparent size of the stars is not seen to alter visibly need not appear entirely improbable to you when you see that men's estimates in such a matter may be so grossly in error, particularly when looking at brilliant objects. Looking, for example, at a burning torch from a distance of two hundred paces, and then coming closer by three or four yards, do you believe that you yourself would perceive it as larger? For my part, I should certainly not discover this even if I approached by twenty or thirty paces; sometimes I have even happened to see such a light at a distance, and been unable to decide whether it was coming toward me or going away, when in fact it was approaching. Now what of this? If the same approach and retreat of Saturn (I mean double the distance from the sun to us) is almost entirely imperceptible, and if it is scarcely noticeable in Jupiter, what could it amount to in the fixed stars, which I believe you would not hesitate to place twice as far away as Saturn? In Mars, which while approaching us. . .

SIMP. Please do not labor this point, for I am indeed convinced that what you have said about the unaltered appearance of the apparent sizes of the fixed stars may very well be the case. But what shall we say to that other difficulty which arises from no variation at all being seen in their changing aspects?

SALV. Let us say something which will perhaps satisfy you also on this point. Briefly, would you be content if those alterations really were perceived in the stars which seem to you so necessary if the annual motion belongs to the earth?

SIMP. I should indeed be, so far as this particular is concerned.

SALV. I wish you had said that if such a variation were perceived, nothing would remain that could cast doubt upon the earth's mobility, since no counter could be found to such an event. But even though this may not make itself visible to us, the earth's mobility Is not thereby excluded, nor its immobility necessarily proved. It is possible, Copernicus declares, that the immense distance of the starry sphere makes such small phenomena unobservable. And as has already been remarked, it may be that up to the present they have not even been looked for, or, if looked for, not sought out in such a way as they need to be; that is, with all necessary precision and minute accuracy. It is hard to achieve this precision, both on account of the imperfection of astronomical instruments, which are subject to much variation, and because of the shortcomings of those who handle them with less care than is required. A cogent reason for putting little faith in such observations is the disagreement we find among astronomers in assigning the places, I shall say not merely of novas and of comets, but of the fixed stars themselves, and even of polar altitudes, about which they disagree most of the time by many minutes.

As a matter of fact, how would you expect anyone to be sure, with a quadrant or sextant that customarily has an arm three or four yards long, that he is not out by two or three minutes in the setting of the perpendicular or the alignment of the alidade? (note: An instrument for angular measurements.) For on such a circumference this will be no more than the thickness of a millet seed. Besides which, it is almost impossible for the instrument to be constructed absolutely accurate and then maintained so. Ptolemy distrusted an armillary instrument constructed by Archimedes himself for determining the entry of the sun

into the equinox.

SIMP. But if the instruments are thus suspect, and the observations are so dubious, how can we ever safely accept them and free them from error? I have heard great vauntings of Tycho's instruments, which were made at enormous expense, and of his remarkable skill in making observations.

SALV. I grant you all this, but neither the one fact nor the other suffices to make us certain in affairs of such importance. I want to have us use instruments far larger than those of Tycho's; quite precise ones, and made at minimum cost, whose sides will be four, six, twenty, thirty, or fifty miles, so that a degree is a mile wide, a minute is fifty yards, and a second is little less than a yard. In a word, we may have them as large as we please, without their costing us a thing.

Being at a villa of mine near Florence, I plainly observed the arrival of the sun at the summer solstice and its subsequent departure. For one evening at its setting it hid itself behind a cliff in the Pietrapana Mountains, about sixty miles away, leaving only a small shred of itself revealed to the north, the breadth of which was not the hundredth part of its diameter. But the following evening, at the same position of setting, it left a like part of itself showing which was noticeably thinner. This is a conclusive proof that it had commenced to move away from the tropic; yet the sun's return between the first and second observations surely did not amount to one second of arc along the horizon. Making the observation later with a fine telescope which would multiply the disc of the sun more than a thousandfold turned out to be pleasant and easy.

Now my idea is for us to make our observations of the fixed stars with similar instruments, utilizing some star in which the changes would be conspicuous. These are, as I have already explained, the ones which are farthest from the ecliptic. Among them Vega, a very large star close to the pole of the ecliptic, would be the most convenient when operating in the manner I am about to describe to you, so far as the more northern countries are concerned, though I am going to make use of another star. I have already been looking by myself for a place well adapted for such observations. The place Is an open plain, above which there rises to the north a very prominent mountain, at the summit of which is built a little chapel facing west and east, so that the ridgepole of its roof may cut at right angles the meridian over some house situated in the plain. I wish to affix a beam parallel to that ridgepole and about a yard above it. This done, I shall seek in the plain that place from which one of the stars of the Big Dipper is hidden by this beam which I have placed, just when the star crosses the meridian. Or else, if the beam is not large enough to hide the star, I shall find the place from which the disc of the star is seen to be cut in half by the beam--an effect which can be discerned perfectly by means of a fine telescope. It will be very convenient if there happens to be some house at the place from which this event can be perceived, but if not, then I shall drive a stick firmly into the ground and affix a mark to indicate where the eye is to be placed whenever the observation is to be repeated. I shall make the first of these observations at the summer solstice, in order to continue them from month to month, or whenever I please, until the other solstice.

By means of such observations, the star's rising or lowering can be perceived no matter how small it may be. And if in the course of these operations any such variation shall happen to become known, how great an achievement will be made in astronomy' For by this means, besides ascertaining the annual motion, we shall be able to gain a knowledge of the size and distance of that same star.

SAGR. I thoroughly understand the whole procedure, and the operations seem to me to be so easy and so well adapted to what is wanted, that it may very reasonably be believed that Copernicus himself, or some other astronomer, has actually performed them.

SALV. It seems the other way around to me, for it is improbable that if anyone had tried this he would not

have mentioned the result, whichever opinion it turned out to favor. But no one is known to have availed himself of this method, for the above or for any other purpose; and without a fine telescope it could not very well be put into effect.

SAGR. What you say completely satisfies me. Now, since quite a while remains until the night, if you want me to find any rest then, I hope it will not be too much trouble for you to explain to us those problems which a little while ago you asked us to put off until tomorrow. Please give us back the reprieve which we extended to you, and abandoning all other arguments explain to us how (assuming the motions which Copernicus attributes to the earth, and keeping immovable the sun and the fixed stars) such events may follow as pertain to the elevation and lowering of the sun, the changing of the seasons, and the inequalities of nights and days, in Just the way that is so easily understood to take place in the Ptolemaic system.

SALV. I must not and cannot refuse anything which Sagredo pleads for. The delay that I requested was only to give me time to rearrange in my mind the premises which are useful for a clear and comprehensive explanation of the manner in which these events take place in the Copernican as well as in the Ptolemaic system. Indeed, more easily and simply in the former than in the latter, so that it may be clearly seen that the former hypothesis is as easy for nature to put into effect as it is hard for the intellect to comprehend. Nevertheless I hope, by utilizing explanations other than those resorted to by Copernicus, to make even the learning of it very much less obscure. In order to do this, I shall set forth some assumptions as known and self-evident, as follows:

First. I assume that the earth is a spherical body which rotates about its own axis and poles, and that every point on its surface traces out the circumference of a circle, greater or lesser according as the designated point is more or less distant from the poles. Of these circles, that one is greatest which is traced out by a point equidistant from the poles. All these circles are parallel to one another, and we shall refer to them as *parallels*.

Second. The earth being spherical in shape and its material being opaque, half its surface is continually lighted and the rest is dark. The boundary which separates the lighted part from the dark being a great circle, we shall call this the boundary circle of light.

Third. When the boundary circle of light passes through the earth's poles It will cut all the parallels into equal sections, it being a great circle; but, not passing through the poles, it will cut them all into unequal parts except the central circle; this, being also a great circle, will be cut into equal parts in any case.

Fourth. Since the earth turns about its own poles, the length of day and night is determined by the arcs of the parallels cut by the boundary circle of light. The arc which remains in the illuminated hemisphere determines the length of the day, and the remainder that of the night.

These things being set forth, we may wish to draw a diagram for a clearer understanding of what comes next. (Fig. 6) First let us indicate the circumference of a circle, to represent for us the orbit of the earth, described in the plane of the ecliptic. This we may divide by two diameters into four equal parts; Capricorn, Cancer, Libra, and Aries, which shall here represent at the same time the four cardinal points; that is, the two solstices and the two equinoxes. And in the center of this circle, let us denote the sun, O, fixed and immovable

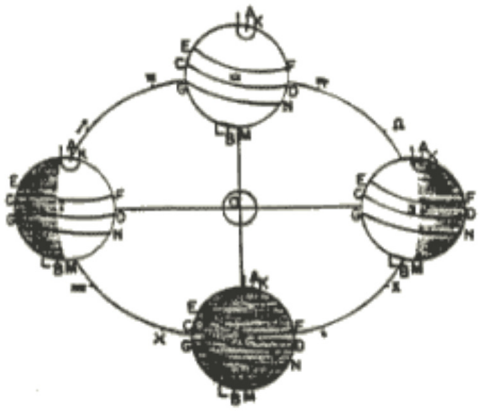

Figure 6

Now with the four points Capricorn, Cancer, Libra, and Aries as centers, we shall draw four equal circles which to us will represent the earth at these four different seasons. The center of the earth travels in the space of a year around the whole circumference Capricorn-Aries-Cancer Libra,) moving from west to east in the order of the signs of the zodiac. It is already evident that when the earth is in Capricorn the sun Will appear in Cancer, the earth moving along the arc from

Capricorn to Aries, the sun will appear to be moving along the arc from Cancer to Libra. In a word, it will run through the signs of the zodiac in their order during the space of a year. So with this first assumption, the apparent annual motion of the sun around the ecliptic is satisfied beyond any argument.

Coming now to the other movement-that is, the diurnal motion of the earth about itself--its poles and axis must be established. These must be understood to be not perpendicularly erect to the plane of the ecliptic; that is, not parallel to the axis of the earth's orbit, but inclined from right angles about twenty-three and one-half degrees, with the North Pole toward the axis of the earth's orbit when the center of the earth is at the solstitial point in Capricorn Assuming, then, that the center of the terrestrial globe Is at that point, let us indicate the poles and the axis AB, tilted twenty-three and one-half degrees from the perpendicular on the Capricorn-Cancer diameter, so that the angle A-Capricorn-Cancer amounts to the complement, or sixty-six and one-half degrees, and this inclination must be assumed to be immutable. We shall take the upper pole, A, to be the north, and the other, B, the south.

If the earth is assumed to revolve about its axis AB in twenty-four hours, also from west to east, circles parallel to one another will be described by all points noted on its surface. In this first position of the earth, we shall designate the great circle CD and the two which are twenty-three and one-half degrees from it--EF above, and GN below--and these others at the two extremes, 1K and LM, at a similar distance from the poles A and B; and we could have drawn countless other circles parallel to these five, traced by innumerable points on the earth. Let us now assume that the earth is transported by the annual motion of its center to the other positions already marked, passing to them according to the following laws: That its own axis AB not only does not change its inclination to the plane of the ecliptic, but that it does not vary its direction, either; remaining thus always parallel to itself, it points continually toward the same parts of the universe, or let us say of the firmament. This means that if we imagine the axis to be prolonged, it would describe with its upper end a circle parallel and equal to the earth' s orbit through Libra, Capricorn, Aries, and Cancer, as the upper base of a cylinder described by itself in its annual motion upon the lower

base, Libra-Capricorn-Aries-Cancer. Hence, because of this unchanging tilt, let us draw these other three figures around the centers of Aries, Cancer, and Libra, exactly similar to the one drawn around the center of Capricorn.

Next let us consider the first diagram of the earth. Because of the axis AB being inclined at twenty-three and one-half degrees toward the sun, and since the arc Al is also twenty-three and one-half degrees, the light of the sun illumines the hemisphere of the terrestrial globe exposed to the sun (of which only half is seen here), divided from the dark part by the boundary of light, IM The parallel CD, being a great circle, will be divided into equal parts by this, but all others will be cut into unequal parts because the boundary of light W does not pass through the poles A and B. The parallel IK together with all others described between it and the pole A, will be entirely within the illuminated part, just as on the other hand the opposite ones toward the pole B and contained within the parallel LM will remain in the dark.

Besides this, since the arc Al is equal to the arc FD, and the arc AF is common to IKF and AFD, the latter two are equal, each being one quadrant; and since the whole arc IFM is a semicircle, the arc MF will also be a quadrant and equal to FKI. Hence the sun, 0, in this position of the earth, will be vertical to anyone. at the point F. But through the diurnal revolution around the fixed axis AB, all points on the parallel EF pass through this same point F, and therefore on such a day the sun at midday will be overhead to all inhabitants of the parallel EF; and to them it will seem to describe by its motion that circle which we call the tropic of Cancer.

But to the inhabitants of all parallels above the parallel EF toward the North Pole, A, the sun is below their zenith toward the south. On the other hand, to all inhabitants of the parallels below EF toward the equator CID and the South Pole B, the midday sun is elevated above the zenith toward the North Pole, A.

Next you may see how of all parallels, only the great circle CD is cut into equal parts by the boundary of light IM, the others above and below this all being cut into unequal parts. Of the upper ones, the semidiurnal arcs (which are those in the part of the earth lighted by the sun) are greater than the seminocturnal ones, which remain in the dark. The contrary happens for the remainder which are beneath the great circle CD toward the pole B; of these, the semidiurnal arcs are smaller than the seminocturnal. Also you may see quite plainly that the differences of these arcs go on increasing as the parallels become closer to the poles, until the parallel IK stays entirely in the lighted part, and its inhabitants have a twenty-four-hour day without night. In contrast to this the parallel LM, remaining all in the dark, has a night of twenty-four hours without day.

Next let us proceed to the third diagram of the earth, here placed with its center at the Cancer point, from which the sun would appear to be at the first point of Capricorn. It Is indeed easy to see that as the axis AB has not changed its tilt, but has remained parallel to itself, the appearance and situation of the earth are precisely the same as in the first diagram, except that the hemisphere which in the first was lighted by the sun remains in shadow here, and the one which was previously dark now becomes illuminated. Hence what occurred in the first diagram is now reversed with respect to the differences of days and nights and their relative length or shortness.

The first thing noticed is that where in the first figure, the circle 1K was entirely in the light it is now all in the dark; and LM, which opposite, is now entirely in the light, where it was previously completely in shadow. Of the parallels between the great circle CD and the pole A, the semidiurnal arcs are now smaller than the seminocturnal, which is the opposite of the first; and of the others toward the pole B, the semidiurnal arcs are now longer than the seminocturnal, likewise the opposite of What took place in the other position of the earth. You may now see the sun made vertical to the inhabitants of the tropic GN, and for those of the parallel EF it is depressed southward through the entire arc ECG; that is, forty-seven

degrees. It has, in short, gone from one tropic to the other, passing through the equator, being raised and then dropped along the meridian through the said interval of forty-seven degrees. This entire change has its origin not in any dropping or rising of the earth; on the contrary, in its never dropping nor rising, but in generally keeping itself always in the same location with respect to the universe and merely going around the sun, which is situated at the center of this same plane in which the earth moves around it in the annual motion.

Here a remarkable phenomenon must be noticed, which is that just as the preservation of the axis of the earth in the same direction with respect to the universe (or let us say toward the highest fixed stars) makes the sun appear to us to rise and fall by as much as forty-seven degrees without any rise or drop in the fixed stars at all, so if on the contrary the earth's axis were continually kept at a given inclination toward the sun (or we might say toward the axis of the zodiac), no alteration of ascent or descent would appear to be made by the sun. Thus the inhabitants of a given place would always have the same periods of night and day, and the same kind or season; that is, some people would always have Writer, some always summer, some spring, etc. But on the other hand, the changes in the fixed stars with regard to rising and falling would then appear enormous to us, amounting to this same forty-seven degrees. For an understanding of this let us go back to a consideration of the position of the earth in the first diagram, where the axis AB is seen with its upper pole A tilted toward the sun. In the third figure the same axis has kept the same direction toward the highest sphere by remaining parallel to itself, so the upper pole A no longer tilts toward the sun but tilts away from it, and lies forty-seven degrees from its first position. Thus, in order to reproduce the same inclination of the pole A toward the sun, it would be required (by turning the globe along its circumference ACBD) to take it forty-seven degrees toward E; and any Fixed star observed on the meridian would be raised or lowered by that many degrees. Now let us proceed with an explanation of the rest, and consider the earth placed in the fourth diagram with its center at the first point of Libra, the sun appearing in the beginning of Aries. Thus the earth's axis, which in the first diagram was assumed to be inclined to the Capricorn-Cancer diameter and hence to be in the same plane as that which cuts the earth's orbit perpendicularly in the Capricorn-Cancer line, when transferred to the fourth figure (being kept always parallel to itself, as we have said), comes to be in a plane which is likewise vertical to the plane of the earth's orbit, and parallel to the one which cuts the latter at right angles along the Capricorn-Cancer diameter. Hence the line from the center of the sun to the center of the earth (from 0 to Libra) Will be perpendicular to the axis BA. But this same line from the center of the sun to the center of the earth is always perpendicular also to the boundary circle of light; therefore this same circle will pass through the poles A and B in the fourth figure, and the axis AB will lie in its plane. But the great circle, passing through the poles of the parallels, will divide them all into equal parts, therefore the arcs IK EF, CD, GN, and LM will all be semicircles, and the lighted hemisphere will be this one which faces us and the sun, and the boundary circle of light will be this very circumference ACBD. And when the earth is at this place, the equinox will occur for all its inhabitants.

The same Will happen in the second diagram, where the earth having its lighted hemisphere toward the sun shows to us its dark side with the nocturnal arcs. These are also all semicircles, and consequently also make an equinox. Finally, since the line produced from the center of the sun to the center of the earth is perpendicular to the axis AB, to which likewise the great circle CD among the parallels is perpendicular, the same line O--Libra necessarily passes through the same plane as the parallel CD, cutting its circumference in the center of the daytime arc CD; therefore the sun will be vertical to anyone located in that cut. But all inhabitants of that parallel pass by there, carried by the earth's rotation, and have the midday sun directly overhead; therefore the sun will appear to all inhabitants of the earth to be tracing out the greatest parallel, called the equatorial circle.

Moreover, the earth being at either of the solstitial points, one of the polar circles IK or LM is entirely in

the light and the other in the shadow; but when the earth is at the equinoctial points, half of each of these polar circles is in the light and the balance in the dark. It should not be hard to see how the earth in passing, for example, from Cancer (where the parallel IK is entirely dark) to Leo, a part of the parallel IK toward the point I will commence to enter the light, and the boundary of light IM will begin to retreat toward the poles A and B, cutting the circle ACBD no longer at I and M, but in two other points failing between the endpoints I, A, M, and B, of the arcs IA and MB. Thus the inhabitants of the circle IK begin to enjoy the light, and those of the circle LM to experience the darkness.

See, then, how two simple noncontradictory motions assigned to the earth, performed in periods well suited to their sizes, and also conducted from west to east as in the case of all movable world bodies, supply adequate causes for all the visible phenomena. These phenomena can be reconciled with a fixed earth only by renouncing all the symmetry that is seen among the speeds and sizes of moving bodies, and attributing an inconceivable velocity to an enormous sphere beyond all the others, while lesser spheres move very slowly. Besides, one must make the motion of the former contrary to that of the latter, and to increase the improbability, must have the highest sphere transport all the lower ones opposite to their own inclination. I leave it to your judgment which has the more likelihood in it.

SAGR. For my part, so far as my senses are concerned, there is a great difference between the simplicity and ease of effecting results by the means given in this new arrangement and the multiplicity, confusion, and difficulty found in the ancient and generally accepted one. For if the universe were ordered according to such a multiplicity, one would have to remove from philosophy many axioms commonly adopted by all philosophers. Thus it is said that Nature does not multiply things unnecessarily; that she makes use of the easiest and simplest means for producing her effects; that she does nothing in vain, and the like.

I must confess that I have not heard anything more admirable than this, nor can I believe that the human mind has ever penetrated into subtler speculations. I do not know how it looks to Simplicio.

SIMP. If I must tell you frankly how it looks to me, these appear to me to me some of those geometrical subtleties which Aristotle reprehended in Plato when he accused him of departing from sound philosophy by too much study of geometry. I have known some very great Peripatetic philosophers, and heard them advise their pupils against the study of mathematics as something which makes the intellect sophistical and inept for true philosophizing; a doctrine diametrically opposed to that of Plato, who would admit no one into philosophy who had not first mastered geometry.

SALV. I endorse the policy of these Peripatetics of yours in dissuading their disciples from the study of geometry, since there is no art better suited for the disclosure of their fallacies. You see how different they are from the mathematical philosophers, who much prefer dealing with those who are well informed about the general <--The Third Day 81--> Peripatetic philosophy than with those who lack such information and because of that deficiency are unable to make comparisons between one doctrine and the other.

But setting all this aside, please tell me what absurdities or excessive subtleties make this Copernican arrangement the less plausible so far as you are concerned.

SIMP. As a matter of fact, I did not completely understand it, perhaps because I am not very well versed either in the way the same effects are produced by Ptolemy--I mean these planetary stoppings, retrograde movements, approaches and retreats, lengthenings and shortenings of the day, alterations of the seasons, etc. But passing over the consequences which stem from the basic assumptions, I feel no small difficulties to exist in these assumptions themselves, and if the assumptions fall to the ground then they bring the whole structure into ruin. Now since the whole framework of Copernicus seems to me to be built upon a

weak foundation (being supported upon the mobility of the earth), then if this were removed, there would be no room for further argument. And to remove it, Aristotle's axiom that to a simple body only one simple motion can be natural appears to be sufficient. Here three movements, if not four, are assigned to the earth, a simple body; and all of them are quite different from one another. For besides the straight motion toward the center, which cannot be denied to it as a heavy body, there are ascribed to it a circular motion in a great circle around the sun in one year, and a whirling upon itself every twenty-four hours, and (what is most extreme, and possibly for that reason you have remained silent about this) another whirling about its own center, completed in a year, and opposite to the previously mentioned twenty-four-hour motion. My mind feels a great repugnance to this....

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THE FOURTH DAY

SAGREDO. I do not know whether you are really arriving later than usual for our accustomed discussion or whether it just seems so to me because of my desire to hear Salviati's thoughts on such an interesting matter. I have been watching through the window for a long time, hoping from one moment to the next to see the gondola come into view which I sent to fetch you.

SALV. I believe it is only your imagination that has made the time drag, rather than any tardiness on our part. But in order not to stretch it still further it will be good for us to get to the matter in hand without wasting any more words.

Let us see, then, how nature has allowed (whether the facts are actually such, or whether at a whim and as if to play upon our fancies) -- has allowed, I say, the movements that have long been attributed to the earth for every reason except as an explanation of the ocean tides to be found now to serve that purpose too, with equal precision; and how, reciprocally, this ebb and flow itself cooperates in confirming. the earth's mobility. Up to this point the indications of that mobility have been taken from celestial phenomena, seeing that nothing which takes place on the earth has been powerful enough to establish the one position any more than the other. This we have already examined at length by showing that all terrestrial events from which it is ordinarily held that the earth stands still and the sun and the fixed stars are moving would necessarily appear just the same to us if the earth moved and the others stood still. Among all sublunary things it is only in the element of water (as something which is very vast and is not joined and linked with the terrestrial. globe as are all its solid parts, but is rather, because of its fluidity, free and separate and a law unto itself) that we may recognize some trace or indication of the earth's behavior in regard to motion and rest. After having many times examined for myself the effects and events, partly seen and partly heard ; from other people, which are observed in the movements of the water; after, moreover, having read and listened to the great follies which many people have put forth as causes for these events, I have arrived at two conclusions which were not lightly to be drawn and granted. Certain necessary assumptions having been made, these are that if the terrestrial globe were immovable, the ebb and flow of the oceans could not occur naturally; and that when we confer upon the globe the movements just assigned to it, the seas are necessarily subjected to an ebb and flow agreeing in all respects with what is to be observed in them.

SAGR. The proposition is crucial, both in itself and in what follows as a consequence; therefore I shall be so much the more attentive in listening to its explanation and verification.

SALV. In questions of natural science like this one at hand, I a knowledge of the effects is what leads to an investigation and discovery of the causes. Without this, ours would be a blind journey, or one even more uncertain than that; for we should not know where we wanted to come out, whereas the blind at least know where they wish to arrive. Hence before all else it is necessary to have a knowledge of the effects whose causes we are seeking. Of those effects you, Sagredo, must be more fully and surely informed than I am, since besides being born in Venice and having long resided here where the tides are famous for their size, you have also sailed to Syria, and, having a clever and curious mind, you must have made many observations. But I, who have only been able to observe for rather a short time what happens here at this end of the Adriatic Gulf, and in our lower sea on the shores of the Tyrrhenian, must often depend upon what others tell me -- which, being for the most part not in good agreement and accordingly rather unreliable, may contribute confusion rather than confirmation to our reflections.

Still, from those accounts which we are sure of, and which happen to cover the principal events, it seems to me possible to arrive at the true and primary causes. I do not presume to be able to adduce all the proper and sufficient causes of those effects which are new to me and which consequently I have had no chance to think about; what I am about to say, I propose merely as a key to open portals to a road never before trodden by anyone, in a firm hope that minds more acute than mine will broaden this road and penetrate further along it than I have done in my first revealing of it. And though in

other seas remote from us events may take place which do not occur in our Mediterranean, nevertheless the reason and the cause which I shall produce will still be true, provided that it is verified and fully satisfied by the events which do take place in our sea; for ultimately one single true and primary cause must hold good for effects which are similar in kind. I shall, then, tell you the story of the effects which I know to exist, and assign to them the cause that is believed by me to be true; and you, gentlemen, shall produce others noticed by you in addition to these of mine, and then we shall see whether the cause I am about to adduce can account for them also.

I say, then, that three periods are observed in the flow and ebb of the ocean waters. The first and principal one is the great and conspicuous daily tide, in accordance with which the waters rise and fall at intervals of some hours; these intervals in the Mediterranean are for the most part about six hours each -- that is, six hours of rising and six more of falling. The second period is monthly, and seems to originate from the motion of the moon; it does not introduce other movements, but merely alters the magnitude of those already mentioned, with a striking difference according as the moon is full, new, or at quadrature with the sun. The third period is annual, and appears to depend upon the sun; it also merely alters the daily movements by rendering them of different sizes at the solstices from those occurring at the equinoxes.

We shall speak first about the diurnal period, as it is the principal one, and the one upon which the actions of the moon and the sun are exercised secondarily in their monthly and annual alterations. Three varieties of these hourly changes are observed; in some places the waters rise and fall without making any forward motion; in others, without rising or falling they move now toward the east and again run back toward the west; and in still others, the height and the course both vary. This occurs here in Venice, where the waters rise in entering and fall in departing. They do this at the end of a gulf extending east I and west and terminating on open shores where the water '. has room to spread out upon rising; if their course were interrupted by mountains or by very high dikes, they would rise and sink against these without any forward motion. Elsewhere the water runs to and fro in its central parts without changing height, as happens notably in the Straits of Messina between Scylla and Charybdis, where the currents are very swift because of the narrowness of the channel. But in the open Mediterranean and around its islands, such as the Balearics, Corsica, Sardinia, Elba, Sicily (on the African side), Malta, Crete, etc., the alterations of height are very small but the currents are quite noticeable, especially where the sea is restrained between islands, or between these and the continent.

Now it seems to me that these actual and known effects alone, even if no others were to be seen, would very probably persuade anyone of the mobility of the earth who is willing to stay within the bounds of nature; for to hold fast the basin of the Mediterranean and to make the water contained within it behave as it does surpasses my imagination, and perhaps that of anyone else who enters more than superficially into these reflections.

SIMP. These events, Salviati, did not just commence; they are very ancient, and have been observed by innumerable men, many of whom have contrived to give one reason or another to account for them. Not far from here there is a great Peripatetic who gives for them a cause recently dredged out of one of Aristotle's texts which had not been well understood by his interpreters. From this text, he deduces that the true cause of these movements stems from nothing else but the various depths of the seas. The deepest waters, being more abundant and therefore heavier, . expel the waters of lesser depth; these, being raised up, then try to descend, and from this continual strife the tides are derived.

Then there are many who refer the tides to the moon, saying that this has a particular dominion over the water. Lately a certain prelate has published a little tract wherein he says that the moon, wandering through the sky, attracts and draws up toward itself a heap of water which goes along following it, so that the high sea is always in that part which lies under the moon. And since when the moon is below the horizon, this rising nevertheless returns, he tells us that he can say nothing to account for this effect except that the moon not only retains this faculty naturally in itself, but in this case has also the power to confer it upon the opposite sign of the zodiac. Others, as I think you know, say that the moon also has power to rarefy the water by its temperate heat, and that thus rarefied, it is lifted up. Nor are those lacking who . . .

SAGR. Please, Simplicio, spare us the rest; I do not think there is any profit in spending the time to recount them, let alone the words to refute them. If you should give assent to any of these or to similar triflings, you would be wronging your own judgment -- just when, as we know, it has been, much unburdened of error.

SALV. I am a little more easygoing than you, Sagredo, and I shall put in a few words for Simplicio's benefit if he thinks that some probability attaches to the things he has been telling us.

Simplicio, I say that waters which have their external surfaces higher expel those that are lower, but not that those which are deeper do so; and the higher waters, having driven away the lower, quickly come to rest and equilibrium. Your Peripatetic must believe that all the lakes in the world (which remain placid) and all the seas where the tide is imperceptible must have perfectly level beds; I was so naIve as to persuade myself that even if there were no other soundings, the Islands whIch rise above the water would be a very obvious indication of the unevenness of the bottoms. You might tell your prelate that the moon travels over the whole Mediterranean every day, but the waters are raised only at its eastern extremity and for us here at Venice.

As for those who make the temperate heat of the moon able to swell the water, you may tell them to put afire under a kettle of water, hold their right hands in this until I the heat raises the water a single inch, and then take them out to write about the swelling of the seas. Or ask them at least to show you how the moon rarefies a certain part. of the water and not the remainder, such as this here at Venice, but not that at Ancona, Naples, or Genoa.

Let us just say that there are two sorts of poetical minds -- one kind apt at inventing fables, and the other disposed to believe them.

SIMP. I do not think that anyone believes fables when he knows them to be such; and as to the opinions about the cause of the tides (which are numerous), since I know that there is only one true and primary cause for one effect, I understand perfectly that at most one can be true, and all the rest must be false and fabulous. Perhaps the true one is not even among those which have been produced up to date. I rather believe this to be so, since it would be remarkable if the true cause should shed so little light as not to show through the darkness of so many false ones. But I must say, with that frankness which is permitted here among ourselves, that to introduce the motion of the earth and make it the cause of the tides seems to me thus far to be a concept no less fictitious than all the rest I have heard. If no reasons more agreeable to natural phenomena were presented to me, I should pass on unhesitatingly to the belief that the tide is a supernatural effect, and accordingly miraculous and inscrutable to the human mind -- as are so many others which depend directly upon the omnipotent hand of God.

SALV. You argue very prudently, and also in agreement with Aristotle's doctrine; at the beginning of his Mechanics; as you know, he ascribes to miracles all things whose causes are hidden. But I believe you do not have any stronger indication that the true cause of the tides is one of : those incomprehensibles than the mere fact that among all I things so far adduced as verae causae there is not one which we can duplicate for ourselves by means of appropriate artificial devices. For neither by the light of the moon or sun, nor by temperate heat, nor by differences of depth can we ever make the water contained in a motionless vessel run to and fro, or rise and fall in but a single place. But if, by simply setting the vessel in motion, I can represent for you without any artifice at all precisely those changes which are perceived in the waters of the sea, why should you reject this cause and take refuge in miracles?

SIMP. I shall have recourse to miracles unless you dissuade me from it by other natural causes than the motion of the containers of the waters of the sea. For I know that the latter containers do not move, the entire terrestrial globe being naturally immovable.

SALV. But do you not believe that the terrestrial globe could be made movable supernaturally, by God's absolute power?

SIMP. Who can doubt this?

SALV. Then, Simplicio, since we must introduce a miracle to achieve the ebbing and flowing of the oceans, let us make the earth miraculously move with that motion by which the oceans are naturally moved. This operation will indeed be as much simpler and more natural among things miraculous, as it is easier to make a globe turn around (which we see so many of them do) than to make an immense bulk of water go back and forth more rapidly in some places than in others;

rise and fall, here more, there less, and in other places not at all, and to make all these variations within the same containing vessel. Besides, these are many miracles, while the other is only one. Add to this that the miracle of making the water move brings another miracle in its train, which ,is that of holding the earth steady against the impulses of the water. For these would be capable of making it vacillate first in one direction and then in the other, if it were not miraculously retained.

SAGR. Let us suspend judgment for a while as to the folly of the new opinion which Salviati wants to explain to us, Simplicio, and not be so quick to class it with those ridiculous older ones. As to the miracle, let us likewise have recourse to that only after we have heard arguments which are restricted within the bounds of nature. Though, indeed, to my mind all works of nature and of God appear miraculous.

SALV. That is the way I feel about it, and saying that the natural cause of the tides is the motion of the earth does not exclude this operation from being miraculous.

Now, returning to our discussion, I reply and reaffirm that it has never previously been known how the waters contained in our Mediterranean basin can make those movements which they are seen to make, so long as this basin and containing vessel rests motionless. What renders the matter puzzling is daily observed, as I am about to describe; therefore, listen carefully.

We are here in Venice, where the waters are now low; the sea is quiet, the air tranquil; the water is commencing to rise, and at the end of five or six hours it will have gone up ten spans or more. This rise is not made by the original water being rarefied, but by water newly arriving here -- water of the same kind as the original water, with the same salinity, the same density, the same weight. Ships float in it, Simplicio, without submerging a hair's-breadth further; a barrel of it weighs not a grain more or less than the same quantity of the other; it keeps the same coldness entirely unchanged; in short, it is water which has recently and visibly entered through the channels and mouths of the Lido.

Now you tell me how and whence it came here. Are there perchance hereabouts some abysses or openings in the bottom of the sea through which the earth draws in and expels the water, breathing like some immense and monstrous whale? If so, why does the water not rise likewise over a space of six hours at Ancona, Dubrovnik (Ragugia), and Corfu, where the increase is small or even imperceptible? Who will find a way to pour new water into an immovable vessel and have it rise only in one definite place and not in others?

Do you perhaps say that this new water is borrowed from the ocean, carried in through the Straits of Gibraltar? This will not remove the difficulties mentioned; it will only make them greater. In the first place, tell me what must be the course of that water which, entering by the strait, is conducted in six hours clear to the extreme coast of the Mediterranean, a distance of tWo or three thousand miles, and retraces the same space on its retUrn? What would become of the ships scattered about on the sea? And what of those in the strait, on a continual watery precipice of immense bulk, entering through a channel no more than eight miles wide -- a channel which must in six hours give passage to enough water to inundate a space hundreds of miles wide and thousands long? Where is the tiger or falcon that ever ran or flew with such speed? A speed, I mean, of 400 miles an hour or better.

It cannot be denied that there are currents running the length of the gulf, but they are so slow that a rowboat can outrun them, though not without losing headway. Besides, if this water comes in through the strait, there is another difficulty: How does it cause so much of a rise here, at so remote a place, without first raising the closer parts by a similar or greater amount? To sum up, I do not believe that either obstinacy or subtleness of wit could ever discover a reply to these difficulties and thereby be able to maintain the fixity of the earth against them, while remaining within natural limitations.

SAGR. So far I follow you very well, and I am anxiously waiting to hear how these marvels can take place unimpeded if we assume the motions already assigned to the earth.

SALV. As these effects must be consequences of the motions which belong naturally to the earth it is not only necessary that they encounter no obstacle or impediment, but that they follow easily. Nor must they merely follow easily; they must

follow necessarily, in such a way that it would be impossible for them to take place in any other manner For such is the property and condition of things which are natural and true.

Having established, then, that it is impossible to explain the movements perceived in the waters and at the same time maintain the immovability of the vessel which contains them, let us pass on to considering whether the mobility of the container could produce the required effect in I the way in which it is observed to take place. Two sorts of .movement may be conferred upon a vessel so that the : water contained in it acquires the property of running first I toward one end and then toward the other, and rise and , sink there. The first would occur when one end is lowered I and then the other, for under those conditions the water, ~ running toward the depressed part, rises and sinks alternately at either end. But since this rising and sinking is I nothing but a retreat from and an approach toward the center of the earth, this sort of movement cannot be attributed to concavities in the earth itself as containing vessels of the waters, For such containers could not have parts I able to approach toward or retreat from the center of the ~ terrestrial globe by any motion whatever that might be assigned to the latter.

The other sort of motion would occur when the vessel was moved without being tilted, advancing not uniformly but with a changing velocity, being sometimes accelerated and sometimes retarded. From this variation it would follow that the water (being contained within the vessel but not firmly adhering to it as do its solid parts) would because of its fluidity be almost separate and free, and not compelled to follow all the changes of its container. Thus the vessel being retarded, the water would retain apart of the impetus already received, so that it would run toward the forward end, where it would necessarily rise. On the other hand, when the vessel was speeded up, the water would retain apart of its slowness and would fall somewhat behind while becoming accustomed to the new impetus, remaining toward the back end, where it would rise somewhat.

These effects can be very clearly explained and made evident to the senses by means of the example of those barges which are continually arriving from Fusina filled with water for the use of this city. Let us imagine to ourselves such a barge coming along the lagoon with moderate speed, placidly carrying the water with which it is filled, when either by running aground or by striking some obstacle it becomes greatly retarded. Now the water will not thereby lose its previously received impetus equally with the barge; keeping its impetus, it will run forward toward the prow, where it will rise perceptibly, sinking at the stern. But if on the other hand the same barge noticeably increases its speed in the midst of its placid course, then the water which it contains (before getting used to this and while retaining its slowness) will stay back toward the stern, where it will consequently rise, sinking at the prow. This effect is indubitable and clear; it may be tested experimentally at any time, and there are three things about it which I want you to note particularly.

The first is that in order to make the water rise at one extremity of the vessel, there is no need of new water, nor need the water run there from the other end.

The second is that the water near the middle does not rise or sink noticeably unless the course of the barge happens to be very fast to begin with, and the object struck or other hindrance which checks it is very strong and unyielding. In such an event this might not only make all the water run forward, but cause most of it to jump right out of the barge; the same would also happen if a very violent impulse were suddenly given to it when it was traveling very slowly. But if to a gentle motion of its own there were added a moderate retardation or acceleration, the parts in the middle (as I said) would rise and sink imperceptibly, and the other parts would rise the less according as they were closer to the middle, and the more according as they were farther from it.

The third thing is that whereas the parts around the center make little change as to rising or sinking with respect to the water at the ends, yet they run to and fro a great deal in comparison with the water at the extremities.

Now, gentlemen, what the barge does with regard to the water it contains, and what the water does with respect to the barge containing it, is precisely the same as what the Mediterranean basin does with regard to the water contained within it, and what the water contained does with respect to the Mediterranean basin, its container. The next thing is for us to prove that it is true, and in what manner it is true, that the Mediterranean and all other sea basins (in a word, that all parts

of the earth) move with a conspicuously uneven motion, even though nothing but regular and uniform motions may happen to be assigned to the globe itself.

SIMP. At first sight this looks like a great paradox to me, though I am no mathematician or astronomer. If it is true that the motion of the whole maybe regular, and that of the parts which always remain attached to it may be irregular, then this is a paradox destroying the axiom which affirms tandem esse rationem totius et partium.

SALV. I shall prove my paradox, Simplicio, and then leave to you the burden of either defending the axiom against it or of bringing the two into accord. My demonstration will be brief and easy; it will depend upon things already dealt with at length in our past conversations, without introducing the slightest word to make it favor the ebb and flow.

We have already said that there are two motions attributed to the terrestrial globe; the first is annual, made by its center along the circumference of its orbit about the ecliptic in the order of D the signs of the zodiac (that is, from west to east), and the other is made by the globe itself revolving around its own center in twenty-four hours (likewise from west to east) around an axis which is somewhat tilted, and not parallel to that of its annual revolution. From the composition of these two motions, each of them in itself uniform, I say that there results an uneven motion in the parts of the earth. In order for this to be understood more easily, I shall explain it by drawing a diagram.

- Figure 28

First I shall describe around the center A the circumference of the earth's orbit BC, on which the point B is taken; and around this as center, let us describe this smaller circle DEFG, representing the terrestrial globe. We shall suppose that its center B runs along the whole circumference of the orbit from west to east; that is, from B toward C. We shall further suppose the terrestrial globe to turn around its own center B from west to east, in the order of the points D, E, F, G, during a period of twenty-four hours. Now here we must carefully note that when a circle revolves around its own center, every part of it must move at different times with contrary motions. This is obvious, considering that when the part of the circumference around the point D is moving toward the left (toward E), the opposite parts, around F, go toward the right (toward G); so that when the point D gets to F, its motion will be contrary to what it was originally when it was at D. Moreover, in the same time that the point E descends, so to speak, toward F, G ascends toward D. Since this contrariety exists in the motion of the parts of the terrestrial surface when it is turning around its own center, it must happen that in coupling the diurnal motion with the annual, there results an absolute motion of the parts of the surface which is at one time very much accelerated and at another retarded by the same amount. This is evident from considering first the parts around D, whose absolute motion will be very swift, resulting from two motions made in the same direction; that is, toward the left. The first of these is part of the annual motion, common to all parts of the globe; the other is that of this same point D, carried also to the left by the diurnal whirling, so that in this case the diurnal motion increases and accelerates the annual motion.

It is quite the opposite with the part across from D, at F. This, while the common annual motion is carrying it toward the left together with the whole globe, is carried to the right by the diurnal rotation, so that the diurnal motion detracts from the annual. In this way the absolute motion -- the resultant of the composition of these tw0 is much retarded.

Around the points E and G, the absolute motion remains equal to the simple annual motion, since the diurnal motion acts upon it little or not at all, tending neither to left nor to right, but downward and upward. From this we conclude that just as it is true that the motion of the whole globe and of each of its parts would be equable and uniform if it were moved with a single motion, whether this happened to be the annual or the diurnal, so is it necessary that upon these two motions being mixed together there results in the parts of the globe this uneven motion, now accelerated and now retarded by the additions and subtractions of the diurnal rotation upon the annual revolution.

Now if it is true (as is indeed proved by experience) that the acceleration and retardation of motion of a vessel makes the contained water run back and forth along its length, and rise and fall at its extremities, then who will make any trouble about granting that such an effect may -- or rather, must -- take place in the ocean waters? For their basins are subjected

to just such alterations; especially those which extend from west to east, in which direction the movement of these basins is made.

Now this is the most fundamental and effective cause of the tides, without which they would not take place. But the particular events observed at different times and places are many and varied; these must depend upon diverse concomitant causes, though all must have some connection with the fundamental cause. So our next business is to bring up and examine the different phenomena which may be the causes of such diverse effects.

The first of these is that whenever the water, thanks to some considerable retardation or acceleration of motion of its containing vessel, has acquired a cause for running toward one end or the other, it will not remain in that state when the primary cause has ceased. For by virtue of its own weight and its natural inclination to level and balance itself, it will speedily return of its own accord; and being heavy and fluid, it will not only return to equilibrium but will pass beyond it, pushed by its own impetus, and will rise at the end where first it sank. But it will not stay there; , by repeated oscillations of travel it will make known to us that it does not want the speed of motion it has received to be suddenly removed and reduced to a state of rest. It wishes this to be slowly reduced, abating little by little. In exactly this way we see that a weight suspended by a cord, once removed from the state of rest (that is, the perpendicular), returns to this and comes to rest by itself, but only after having gone to and fro many times, passing beyond this perpendicular position in its coming and going.

The second event to be noticed is that the reciprocations of movement just mentioned are made and repeated with greater or less frequency (that is, in shorter or longer times) according to the various lengths of the vessels containing the water. In the shorter space, the reciprocations are more frequent, and they are rarer in the longer, just as in the above example of the plumb bobs the reciprocations of those which are hung on long cords are seen to be less frequent than those hanging from shorter threads.

For the third remark, you must know that it is not only a greater or lesser length of vessel which causes the water to perform its reciprocations in different times, but a greater or less depth does the same thing. It happens that for water contained in vessels of equal length but of unequal depth, the deeper water will make its vibrations in briefer times, and the oscillations will be less frequent in the shallower.

Fourth, such vibrations produce two effects in water which are worthy of being noticed and observed carefully. One is the alternating rising and falling at either extremity; the other is the horizontal moving and running to and fro, so to speak. These two different motions inhere differently in different parts of the water, The extreme ends of the water rise and fall the most; the central parts do not move, up and down at all; and other parts, by degrees as they are nearer to the ends, rise and fall proportionately more than .those farther from the ends. On the other hand, the central parts move a great deal in that other (progressive) movement back and forth, going and returning, while the waters in the extreme ends have none of this motion -- except so far as they may in rising happen to go higher than their banks, and spill out of their original channel and container. But where the hindrance of the banks restrains them, they merely rise and fall; nor does this prevent the waters in the middle from running back and forth, as do the other parts in proportion, traveling the more or the less according as they are located farther from or closer to the middle.

The fifth particular event must be more carefully considered, because it is impossible for us to duplicate its effects by any practical experiment. It is this: In an artificial vessel like the barge mentioned previously, moving now more rapidly and again more slowly, the acceleration or retardation is always shared uniformly by the whole vessel and by each of its parts. Thus, for example, when the barge is checked in its motion, its forward parts are no more retarded than its after parts, but all share equally in the same retardation. The same happens in acceleration; that is, conferring some new cause of greater velocity upon the barge accelerates the bow in the same way as the stern. But in immense vessels, such as long sea bottoms (though these indeed are nothing more than cavities made in the solidity of the terrestrial globe), it nevertheless happens remarkably enough that their extremities do not increase and decrease in speed jointly, equally, and in the same instant of time. For it may happen that when one extremity of such a vessel is greatly retarded in its motion by virtue of a composition of these two motions, annual and diurnal, the other extremity may be affected by and involved in even a very

swift motion. For your easier comprehension, let us explain this by going back to the diagram previously drawn. Let us suppose a stretch of sea to be as long as one quadrant; the arc BC, for instance. Then the parts near B are, as I said before, in very swift motion because the two movements (annual and diurnal) are united in the same direction, and the parts near C are at that time in retarded motion, since they lack the forward movement depending upon the diurnal motion. If we suppose, I say, a sea bottom as long as the arc BC, we shall see at once that its extremities are moving very unequally at a given time. A stretch of sea as long as a semicircle and placed in the position of the arc BCD will have exceedingly different speeds, since the extremity B would be in very rapid motion, Din very slow motion, and the parts in the middle around C in moderate motion. In proportion as these stretches of sea were shorter, they would participate less in this strange phenomenon of having their parts diversely affected at certain times of day by speed and by slowness of motion.

- Figure 29

Now if in the first place we see experimentally that an acceleration and a retardation shared equally by all parts of the containing vessel may indeed be the cause of the contained water running back and forth, then what must we suppose would happen in a vessel so remarkably situated that a retardation and an acceleration of motion are conferred very unevenly upon its parts? Certainly we cannot help saying that there would necessarily be perceived still greater and more marvelous causes of commotions in the water, and stranger ones. And though to many people it may seem impossible for us to test the effects of such events in artificial devices and vessels, nevertheless this is not entirely impossible; I have a mechanical model in which the effects of these marvelous compositions of movements may be observed in detail. But so far as our present purpose is concerned, what we have grasped intellectually up to this point is sufficient.

SAGR. For my part, I understand well enough that this remarkable phenomenon must necessarily exist in the ocean beds, especially in those which extend a long distance east and west; that is, along the direction of the movements of the terrestrial globe. And as the phenomenon is in a certain sense undreamed of and without parallel among the movements it is possible for us to make, it is not hard for me to believe that it may produce effects which cannot be imitated in our artificial experiments.

SALV. These things being cleared up, it is now time to examine in all their diversity the particular events which are observed experientially in the ebbing and flowing of the waters. First, it cannot be hard for us to understand why it happens that in lakes, pools, and even in small seas there is no noticeable tide. There are two impelling reasons for this. One is that because of the shortness of their basins they acquire at different hours of the day varying degrees of speed, but with little difference occurring among all their parts; they are uniformly accelerated and retarded as much in front as behind; that is, to the east as to the west. And they acquire such alterations, moreover, little by little, and not through the opposition of a sudden obstacle and hindrance, or a sudden and great acceleration in the movement of the containing vessel. The latter, with all its parts, becomes slowly and equally impressed with the same degree of velocity, and from this uniformity it follows that the contained water also receives the same impressions with little resistance or hesitation. Consequently the signs of rising and falling or of running to one extremity or the other are exhibited only obscurely. This effect is also clearly seen in small artificial vessels, in which the contained water is impressed with the same degrees of speed, whenever the acceleration or retardation is made in slow and uniform increments. But in the basins of oceans which extend a great distance from east to west, the acceleration or retardation is much more noticeable and uneven when one extremity of them is in a very retarded motion and the other is moving quickly.

The second reason is the reciprocal oscillation of the water instituted by the impetus already received from the motion of its container, which oscillation (as we have remarked) makes its vibrations with high frequency in small vessels. There inheres in the terrestrial movements a cause for conferring a movement upon the waters only from one twelve-hour period to another, since only once a day is the movement of the containing vessel exceedingly accelerated or retarded.. Now this second cause depends upon the weight of the water, which seeks to restore it to equilibrium, and it produces oscillations of one, two, or three hours, and so on, according to the shortness of the vessel. Thus the whole movement becomes entirely insensible upon this one being combined with the first, which even by itself remains very small for small vessels. For the

primary cause, which has a period of twelve hours, will not have finished impressing its disturbance when overtaken and reversed by this second one depending upon the weight of the water and having a vibration time of one, two, three, or four hours, and so on, according to the shortness and depth of the basin. Acting contrary to the first cause, this perturbs and removes that without ever allowing it to attain the height, or even the average of its motion. Any evidence of ebbing or flowing is entirely annihilated by this conflict, or is very much obscured. I say nothing of the continual changing of the wind, which by disquieting the water would not permit us to be sure of some very small rising or falling, of half an inch or less, which might actually belong to the basins and containers of bodies of water no more than one degree or so in length.

Now, secondly, I shall resolve the question why, since there resides in the primary principle no cause of moving the waters except from one twelve-hour period to another (that is, once by the maximum speed of motion and once by its maximum slowness), the period of ebbing and flowing nevertheless commonly appears to be from one six-hour period to another. Such a determination, I say, can in no way come from the primary cause alone. The secondary causes must be introduced for it; that is, the greater or lesser length of the vessels and the greater or lesser depth of the waters contained in them. These causes, although they do not operate to move the waters (that action being from the primary cause alone, without which there would be no tides), are nevertheless the principal factors in limiting the duration of the reciprocations, and operate so powerfully that the primary cause must bow to them. Six hours, then, is not a more proper or natural period for these reciprocations than any other interval of time, though perhaps it has been the one most generally observed because it is that of our Mediterranean, which has been the only place practicable for making observations over many centuries. Even so, this period is not observed everywhere in it; in some of the narrower places, such as the Hellespont and the Aegean, the periods are much briefer, and they are also quite variable among themselves. Some say it was because of these differences and the incomprehensibility of their causes to Aristotle that he, after observing them for a long time from some cliffs of Euboea (Negroponte), plunged into the sea in a fit of despair and willfully destroyed himself.

In the third place we shall see very readily the reason why a sea like the Red Sea, although very long, is nevertheless quite devoid of any tide. This is so because its length does not extend from east to west, but runs from southeast to northwest. The movements of the earth being from west to east, the impulses of the water are always aimed against the meridians and not from one parallel to another. Hence in seas which extend lengthwise toward the poles and are narrow in the other direction, there is no cause of tides -- unless it is that of sharing those of some other sea with which they may communicate and which is subject to large movements.

We can very easily understand, in the fourth place, the reasons why the ebbing and flowing are greatest at the extremities of gulfs as to rising and falling of the waters, and least in the middle parts. Daily experience shows us this here in Venice, sitUated at the end of the Adriatic, where the difference commonly amounts to as much as five or six feet; but in parts of the Mediterranean distant from the extremities such changes are very small; as at the islands of Corsica and Sardinia, and on the coasts at Rome and Leghorn, where they do not exceed half a foot. We understand also why, on the other hand, where the rising and falling are small, the running to and fro is large. It is a simple thing, I say, to understand the cause of these events, because we have examples of them easily observable in all sorts of artificially manufactured vessels, in which the same effects are seen to follow naturally when we move them unevenly; that is, now accelerating and now retarding them.

Let us consider further, in the fifth place, how a given quantity of water moving slowly in a spacious channel must run very impetuously when it has to pass through a narrow place. From this we shall have no difficulty in understanding the cause of the great current which is created in the narrow channel that separates Calabria from Sicily. For all the water pent up by the extensive island and the Ionian Gulf in the eastern part of the sea, though because of the spaciousness there it descends slowly toward the west, yet upon being restrained in the Straits of Messina between Scylla and Charybdis, it drops rapidly and makes a great agitation. Something similar to this, but greater, is said to occur between Africa and the great island of Madagascar (San Lorenzo), when the waters of the two great Indian and South Atlantic (Etiopico) oceans, in whose midst this lies, must be restricted in their running into the still smaller channel between it and the coast of South Africa. The currents in the Straits of Magellan must be extremely great, communicating between the South Atlantic and the South Pacific oceans.

In the sixth place, in order to give reasons for some more recondite and curious events that are observed in this field, it remains now for us to make another important reflection upon the two principal causes of the tides, thereafter compounding them and mixing them together. The first and simplest of these, as I .have often said, is the definite acceleration and retardation of the parts of the earth from which the waters receive a determinate period, running toward the east and returning to the west within a space of twenty-four hours. The other depends upon the water's own weight, which, once moved by the primary cause, tries then to restore itself to equilibrium by repeated oscillations which are not determinate as to one preestablished time alone, but which have differences of duration according to the different lengths and depths of the containers and basins of the oceans. In so far as they depend upon this second principle, some would flow and return in one hour, some in two, in four, in six, in eight, in ten, etc.

Now if we commence to add the first cause, which has an established period of twelve hours, to the second when it has for example a period of five, then it will sometimes happen that the primary and secondary causes agree in making their impulses both in the same direction; and in such a conjunction (or, so to speak, in such a unanimous conspiracy) the tides will be very great. At other times it happens that the primary impulse becomes in a certain sense contrary to that brought by the secondary; and in such encounters one impulse takes away what the other gives, so that the motion of the waters is weakened and the sea is reduced to a very peaceful and practically motionless state. At still other times, when the two principles are not in opposition nor yet entirely unified, they cause other variations in the rise and fall of the tides.

It may also happen that two very large seas which are in communication through some narrow channel are found to have, because of the mixture of the two principles of motion, a cause of flood in one at the very time the other is having the contrary movement. In this case extraordinary agitations are made in the channel through which they communicate, with opposing motions and vortexes and most dangerous churnings, of which in fact we hear continual tales and accounts. From such discordant movements, depending not only upon different situations and lengths, but even more upon the differing depths of the communicating seas, there sometimes arise various disorderly and unobservable aquatic commotions whose causes have perturbed sailors very much, and still do, when encountered in the absence either of gusts of wind or other significant atmospheric changes which might account for them.

Now these disturbances of the air must be carefully taken into consideration with the other phenomena, and regarded as a third occasional cause capable of greatly altering our observations of effects dependent upon the primary and more essential causes. For there is no doubt that strong winds blowing continuously from the east, for instance, may sustain the waters, preventing their ebb. If then a second recurrence of the high tide, and even a third, is added at the established hours, the waters will swell up very high. In such away, sustained for several days by the force of the wind, they may be raised much more than usual, and make extraordinary floods. We must also take notice of another cause of movement, and this will be our seventh problem. This depends upon the great quantity of water from the rivers that empty into seas which are not vast, for which reason the water is seen to run always in the same direction in channels or straits through which such seas communicate, as happens in the Thracian Bosporus below Constantinople, where the water runs always from the Black Sea toward the Sea of Marmara (Propontide). For the Black Sea the principal causes of ebb and flow are not very effective, because of its shortness; while on the other hand very large rivers empty into it, and this great flow of water must be passed and disgorged through the strait, where the current is quite famous and is always toward the south. Moreover, we must take note that this strait or channel, though it is certainly very narrow, is not subjected to any such perturbations as the strait between Scylla and Charybdis; for the former has the Black Sea above it to the north, with the Sea of Marmara, the Aegean Sea, and the Mediterranean adjoining it to the south -- though over a long tract, and, as we have already noted, however long a sea may be from north to south, it is not subject to tides. But since the Sicilian strait is situated between parts of the Mediterranean, extending a great distance from west to east -- that is, with the tidal currents -- the agitations in it are very great. They would be still greater at the Gates of Hercules, if the Straits of Gibraltar were less open; and the currents in the Straits of Magellan are reported to be extremely strong.

This is all that occurs to me at present to tell you about the causes of this basic diurnal period of the tides, and of their various incidental phenomena. If anything is to be brought up in connection with these, it may be done now; then we may proceed to the other two periods, the monthly and the annual.

SIMP. I do not think it can be denied that your argument goes along very plausibly, the reasoning being ex suppositions, as we say; that is, assuming that the earth does move in the two motions assigned to it by Copernicus. But if we exclude these movements, all the rest is vain and invalid; and the exclusion of this hypothesis is very clearly pointed out to us by your own reasoning. Under the assumption of the two terrestrial movements, you give reasons for the ebbing and flowing; and vice versa, arguing circularly, you draw from the ebbing and flowing the sign and confirmation of those same two movements. Passing to a more specific argument, you say that on account of the water being a fluid body and not firmly attached to the earth, it is not rigorously constrained to obey all the earth's movements. From this you deduce its ebbing and flowing.

In your own footsteps, I argue the contrary and say: The air is even more tenuous and fluid than the water, and less affixed to the earth's surface, to which the water adheres (if for no other reason) because of its own weight, which presses its own much more than the very light air. Then so much the less should the air follow the movements of the earth; hence if the earth did move in those ways, we, its inhabitants, carried along at the same velocity, would have to feel a wind from the east perpetually beating against us with intolerable force. That such would necessarily follow, daily experience informs us; for if, in riding post with no more speed than eight or ten miles an hour in still air, we feel in our faces what resembles a wind blowing against us not lightly, just think what our rapid course of eight hundred or a thousand miles per hour would have to produce against air which was free from such motion! Yet we feel nothing of any such phenomenon.

SALV. To this objection, which seems so persuasive, I reply that it is true that the air is much more tenuous and much lighter than the water, and by its lightness is much less adherent to the earth than heavy and bulky water. But the consequence which you deduce from these conditions is false; that is, that because of its lightness, tenuity, and lesser adherence to the earth it must be freer than water from following the movements of the earth, so that to us who participate completely in those movements its disobedience would be made sensible and evident. In fact, quite the opposite happens. For if you will remember carefully, the cause of the ebbing and flowing of the water assigned by us consisted in the water not following the irregularity of motion of its vessel, but retaining the impetus which it had previously received, and not diminishing it or increasing it in the exact amount by which this is increased or diminished in the vessel. Now since disobedience to a new increase or diminution of motion consists in conservation of the original received impetus, that moving body which is best suited for such conservation will also be best fitted for exhibiting the effect that follows as a consequence of this conservation. How strongly water is disposed to preserve a disturbance once received, even after the cause impressing it has ceased to act, is demonstrated I to us by the experience of water highly agitated by strong winds. Though the winds may have ceased and the airs become tranquil, such waves remain in motion for along time, as the sacred poet so charmingly sings: Qual l'alto Egeo, etc. The continuance of the commotion in this way depends upon the weight of the water, for as has been said on other occasions, light bodies are indeed much easier to set in motion than heavier ones, but they are also much less able to keep the motion impressed upon them, once the cause of motion stops. The air, being a thing that is in itself very tenuous and extremely light, is most easily movable by the slightest force; but it is also most inept at conserving the motion when the mover ceases acting.

As to the air that surrounds the terrestrial globe, I shall therefore say that it is carried around by its adherence no less than the water, and especially those parts of it which are contained in vessels, these vessels being plains surrounded by mountains. And we may much more reasonably declare that such parts are carried around, swept along by the roughness of the earth, than that the higher parts are swept along by the celestial motion as the Peripatetics assert.

What I have said so far seems to me to be an adequate reply to Simplicio's objection. But I want to give him more than satisfaction by means of a new objection and another reply, founded upon a remarkable experiment, and at the same time substantiate for Sagredo the mobility of the earth.

I have said that the air, and especially that part of it which is not above the highest mountains, is carried around by the roughness of the earth's surface. From this it seems to follow that if the earth were not uneven, but smooth and polished, there would be no reason for its taking the air along as company, or at least for its conducting it with so much uniformity. Now the surface of this globe of ours is not all mountainous and rough, but there are very large areas that are quite

smooth; such are the surfaces of the great oceans. These, being also quite distant from the mountain ranges that encirc1e them, appear not to have any aptitude for carrying along the air above them; and whatever may follow as a consequence of not carrying it ought therefore to be felt in such places.

SIMP. I also wanted to raise this same objection, which seems to me very powerful.

SALV. You may well say this, Simplicio, in the sense that from no such thing being felt in the air as would result from this globe of ours going around, you argue its immobility. But what if this thing that you think ought to be felt as a necessary consequence were, as a matter of fact, actually felt? Would you accept this as a sign and a very powerful argument of the mobility of this same globe?

SIMP. In that case it would not be a matter of dealing with me alone; for if this should happen and its cause were hidden from me, perhaps it might be known to others.

SALV. So no one can ever win against you, but must always lose; then it would be better not to play. Nevertheless, in order not to cheat our umpire, I shall go on.

We have just said, and will now repeat with some additions, that the air, as a tenuous and fluid body which is not solidly attached to the earth, seems to have no need of obeying the earth's motion, except in so far as the roughness of the terrestrial surface catches and carries along with it that part of the air which is contiguous to it, or does not exceed by any great distance the greatest altitude of the mountains. This portion of the air ought to be least resistant to the earth's rotation, being filled with vapors, fumes, and exhalations, which are materials that participate in the earthy properties and are consequently naturally adapted to these same movements. But where the cause for motion is lacking -- that is, where the earth's surface has large flat spaces and where there would be less admixture of earthy vapors -- the reason for the surrounding air to obey entirely the seizure of the terrestrial rotation would be partly removed. Hence, while the earth is revolving toward the east, a beating wind blowing from east to west ought to be continually felt in such places, and this blowing should be most perceptible where the earth whirls most rapidly; this would be in the places most distant from the poles and closest to the great circle of the diurnal rotation.

Now the fact is that actual experience strongly confirms this philosophical argument. For within the Torrid Zone (that is, between the tropics), in the open seas, at those w parts of them remote from land, just where earthy vapors are absent, a perpetual breeze is felt moving from the east with so constant a tenor that, thanks to this, ships prosper in their voyages to the West Indies. Similarly, departing from the Mexican coast, they plow the waves of the Pacific Ocean with the same ease toward the East Indies, which are east to us but west to them. On the other hand, voyages from the Indies eastward are difficult and uncertain, nor may they in any case be made along the same routes, but must be piloted more toward the land so as to find other occasional and variable winds caused by other principles, such as we dwellers upon terra firma continually experience. There are many and various reasons for the origin of such winds which we need not bother to bring up at present. These occasional winds blow indifferently toward all f parts of the earth, disturbing seas distant from the equator and bordered by the rough surface of the earth. This amounts to saying that such seas are subjected to those disturbances of the air which interfere with the primary current of air that would be felt continually, especially on the ocean, if such accidental disturbances were lacking.

Now you see how the actions of the water and the air show themselves to be remarkably in accord with celestial observations in confirming the mobility of our terrestrial globe.

SAGR. Yet in order to cap all this, I wish also to tell you one particular which seems to me to be unknown to you, yet which confirms this same conclusion. You, Salviati, have mentioned that phenomenon which sailors encounter in the tropics; I mean that constant wind blowing from the east, of which I have heard accounts from those who have made the voyage quite often. Moreover, it is an interesting fact that sailors do not call this a "wind," but have some other name for it which slips my mind, taken perhaps from its even tenor. When they encounter it, they tie up their shrouds and the other cordage of the sails, and without ever again having any need to touch these, they can continue their voyage in security, or

even asleep. Now this perpetual breeze has been known and recognized by reason of its blowing continuously without interruption; for if other winds had interrupted it, it would not have been recognized as a singular effect different from all the others. From this I may infer that the Mediterranean Sea might also participate in such a phenomenon, but that this escapes unobserved because it is frequently interrupted by other supervening winds. I say this advisedly, and upon very probable theories which occurred to me from what I had occasion to learn during the voyage I made to Syria when I went to Aleppo as consul of our nation. Keeping a special record and account of the days of departure and arrival of ships at the ports of Alexandria, Alexandretta, and here at Venice, I discovered in these again and again that, to my great interest, the returns here (that is, the voyages from east to west over the Mediterranean) were made in proportionately less time than those in the opposite direction, in a ratio of 25 per cent. Thus we see that on the whole the east winds are stronger than those from the west.

SA LV. I am glad to know of this detail, which contributes not a little confirmation to the mobility of the earth. And though it may be said that all the water of the Mediterranean pours perpetually through the Straits of Gibraltar, having to disgorge into the ocean all the waters of so many rivers that empty into it, I do not believe that the current can be so strong that it alone could make such a remarkable difference. This is also evident from seeing that the water at Pharos runs back toward the east no less than it courses toward the west.

SAGR. I, who unlike Simplicio, have not been worrying about convincing anybody besides myself, am satisfied with what has been said regarding this first part. Therefore, Salviati, if you wish to proceed, I am ready to listen.

SALV. I am yours to command; but I should like to hear also how it looks to Simplicio, for from his judgment I can estimate how much I may expect from these arguments of mine in the Peripatetic schools, should they ever reach those ears.

SIMP. I do not want you to take my opinion asa basis for guessing at the judgments of others. As I have often said, I am among the tyros in this sort of study, and things which would occur to those who have penetrated into the profoundest depths of philosophy might never occur to me; for, as the saying goes, I have hardly greeted its doorkeeper. Yet to show some spark of fire, I shall say that as for the effects recounted by you, and this last one in particular, it seems possible to me to render quite sufficient reasons from the mobility of the heavens alone, without introducing any novelties beyond the mere converse of what you yourself have brought into the field.

It is admitted by the Peripatetic school that the element of fire and a large part of the air are carried around in the diurnal rotation from east to west by contact with the lunar sphere as their containing vessel. Now without deviating from your footprints, I should like us to establish the quantity of air participating in that motion as that part which ~ comes down about to the summits of the highest mountains, and would extend on down to the earth itself if the obstacle presented by these very mountains did not hinder it. Thus, just as you declared that the air surrounding the mountain ranges is carried around by the roughness of the moving earth, we say the converse-- that all the element of air is carried around by the motion of the heavens except that part which is lower than the mountain peaks, this being impeded by the roughness of the immovable earth. And where you would say that if such roughness were removed, this would also free the air from being caught, we may say that if this roughness were removed, all the air I would proceed in this movement. And since the surfaces of the open seas are smooth and level, the motion of the breeze which blows perpetually from the east continues there, and is more noticeable at places near the equator, within the tropics, where the motion of the heavens is most rapid.

And as this celestial movement is powerful enough to carry the free air with it, we may say quite reasonably that it contributes this same motion to the movable water. For this is fluid, and unattached to the earth's immobility. We may affirm this with the more confidence in view of your own admission that such a movement need be only very small with respect to its effective cause, which, going around the entire terrestrial globe in one natural day; passes over many thousands of miles per hour (especially near the equator), while currents in the open sea move but a very few miles per hour. In this way our voyages toward the west would be much more convenient and rapid, being assisted not only by the perpetual eastern breeze, but also by the course of the waters.

Perhaps from that same coursing of the water, tides also may arise; the water, striking against the variously situated shores, might even return straight back in the opposite direction, as experience shows us in the courses of rivers. For there the water, because of the irregularity of the banks, often meets some part which juts out or which makes a hollow from beneath, and it whirls around and is seen to return perceptibly. Hence it seems to me that the same effects from which you argue the mobility of the earth (and which mobility you offer as a cause for them) may be sufficiently explained if we hold the earth fixed and restore the mobility to the heavens.

SALV. It cannot be denied that your argument is ingenious and carries something of probability, but I say that this is a probability in appearance only and not in reality. There are two parts to your argument; in the first, you render a reason for the continual motion of the eastern breeze, and also for the motion of the water; in the second, you wish also to obtain a cause for the tides from the same source. The first part, as I have said, has some semblance of probability, though much less than we achieve from terrestrial motion. The second part is not only entirely improbable, but is absolutely impossible and false.

As to the first, in which you say that the hollow of the lunar sphere sweeps along with it the element of fire and all the air down to the summits of the highest mountains, I say first that there is doubt whether any element of fire exists. Even assuming that it does, it is extremely doubtful whether the lunar sphere exists; or indeed, whether any of the other "spheres" do. That is to say, it is questionable whether there actually are such bodies, solid and extremely vast, or whether beyond the air there does not rather extend a continuous expanse of a substance very much more tenuous and pure than our air, and whether the planets do not wander through this, as is now commencing to be held even by most of these same philosophers.

But however that may be, there is no reason for us to believe that fire, by simple contact with a surface which you yourself consider to be remarkably smooth and even, should in its entire extent be carried around in a motion foreign to its own inclination. This has been proved throughout II Saggiatore, and demonstrated by sensible experiments. Beyond this, there is the further improbability of such motions being transferred from most subtle fire to the air, which is much denser, and then from this to water.

But that a body of very rough and mountainous surface, by revolving, should conduct along with it the contiguous air which strikes against its prominences is not merely probable, but necessary; it may be seen from experience, although I believe that even without seeing it no one would cast doubt upon it.

As for the rest, assuming that the air and even the water were conducted by the motion of the heavens, such a motion would have nothing whatever to do with the tides. For since from one uniform cause only one single uniform effect can follow, there would have to be discovered in the waters a continual and uniform current from east to west, existing only in those oceans which, returning upon themselves, encircle the globe. In inland seas such as the Mediterranean, hemmed in as it is on the east, there could be no such motion. For if its waters were driven by the course of the heavens toward the west, it would have been dried up many centuries ago; besides which, our waters do not run only toward the west, but return back toward the east in regular periods. If indeed you should say, from the example of the rivers, that the course of the seas was originally from east to west only, but that the different situations of their shores might force some of the water to flow in reverse, then I shall grant you this, Simplicio; but you must take note that wherever the water is moved back for this reason, it perpetually returns again, while where it runs forward, it always keeps going in the same direction, as you may see from your example of the rivers. As to the tides, you must discover and bring forth reasons for making them run now one way and now the other at the same place--effects which, being contrary and irregular, you can never deduce from one uniform and constant cause. This, as well as overthrowing the idea of a motion being contributed to the sea by the diurnal movement of the heavens, also defeats those who would like to grant to the earth only the diurnal motion and who believe that with this alone they can give a reason for the tides. For since the effect is irregular, it is necessarily required that its causes shall be irregular and variable.

SIMP. I have nothing further to say; neither on my own account, because of my lack of inventiveness, nor on that of

others, because of the novelty of the opinion. But I do indeed believe that if this were broadcast among the schools, there would be no lack of philosophers who would be able to cast doubt upon it.

SAGR. Then let us wait until that happens. In the meantime, if it is satisfactory with you, Salviati, let us proceed.

SALV. Everything that has been said up to this point pertains to the diurnal period of the tides, of which the primary and universal cause has first been proved, without which no effect whatever would take place. Next, passing on to the particular events to be observed in this diurnal period (which vary and are in a certain sense irregular), the secondary and concomitant causes upon which these depend remain to be dealt with.

Now two other periods occur, the monthly and the annual. These do not introduce new and different events beyond those already considered under the diurnal period, but they act upon the latter by making them greater or less at different parts of the lunar month and at different seasons of the solar year -- almost as though the moon and sun were taking part in the production of such effects. But that concept is completely repugnant to my mind; for seeing how this movement of the oceans is a local and sensible one, made in an immense bulk of water, I cannot bring myself to give credence to such causes as lights, warm temperatures, predominances of occult qualities, and similar idle imaginings. These are so far from being actual or possible causes of the tides that the very contrary is true. The tides are the cause of them; that is, make them occur to mentalities better equipped for loquacity and ostentation than for reflections upon and investigations into the most hidden works of nature. Rather than be reduced to offering those wise, clever, and modest words, "I do not know," they hasten to wag their tongues and even their pens in the wildest absurdities.

We see that the moon and the sun do not act upon small receptacles of water by means of light, motion, and great or moderate heat; rather, we see that to make water rise by heat, one must bring it almost to boiling. In short, we cannot artificially imitate the movement of the tides in any way except by movement of the vessel. Now should not these observations assure anyone that all the other things produced as a cause of this effect are vain fantasies, entirely foreign to the truth of the matter?

Thus I say that if it is true that one effect can have only one basic cause, and if between the cause and the effect there is a fixed and constant connection, then whenever a fixed and constant alteration is seen in the effect, there must be a fixed and constant variation in the cause. Now since the alterations which take place in the tides at different times of the year and of the month have their fixed and constant periods, it must be that regular changes occur simultaneously in the primary cause of the tides. Next, the alterations in the tides at the said times consist of nothing more than changes in their sizes; that is, in the rising and lowering of the water a greater or less amount, and its running with greater or less impetus. Hence it is necessary that whatever the primary cause of the tides is, it should increase or diminish its force at the specific times mentioned. But it has already been concluded that an irregularity and unevenness in the motion of the vessel containing the water is the primary cause of the tides; therefore this unevenness must become correspondingly still more irregular from time to time (that is, must increase or diminish).

Now we must remember that the unevenness (that is, the varying velocity of the vessels which are parts of the earth's surface) depends upon these vessels moving with a composite motion, the resultant of compounding the annual and the diurnal motions which belong to the entire terrestrial globe. Of these the diurnal whirling, with its alternate addition to and subtraction from the annual movement, is the thing that produces the unevenness of the compound motion. Thus the primary cause of the uneven motion of the vessels, and hence of that of the tides, consists in the additions and subtractions which the diurnal whirling makes with respect to the annual motion. And if these additions and subtractions were always made in the same proportion with respect to the annual motion, the cause of tides would indeed continue to exist, but only a cause for their being perpetually made in the same manner. Now we must find a reason for these same tides being made greater and less at different times; hence, if we wish to preserve the identity of the cause, there is a necessity of finding changes in these additions and subtractions, making them more and less potent at producing those effects which depend upon them. But I do not see how this can be done accept by making these additions and subtractions, now greater and now less, so that the acceleration and retardation of the composite motion shall be made now in a greater and now in a lesser ratio.

SAGR. I feel myself being gently led by the hand; and although I find no obstacles in the road, yet like the blind I do not see where my guide is leading me, nor have I any means of guessing where such a journey must end.

SALV. There is a vast difference between my slow philosophizing and your rapid insights; yet in this particular with which we are now dealing, I do not wonder that even the perspicacity of your mind is beclouded by the thick dark mists which hide the goal toward which we are traveling. All astonishment ceases when I remember how many hours, how many days, and how many more nights I spent on these reflections; and how often, despairing of ever understanding it, I tried to console myself by being convinced, like the unhappy Orlando, that could not be true which had been nevertheless brought before my very eyes by the testimony of so many trustworthy men. So you need not be surprised if for once, contrary to custom, you do not foresee the goal. And if you are nevertheless dismayed, then I believe that the outcome (which so far as I know is entirely unprecedented) will put an end to this puzzlement of yours.

SAGR. Well, thank God for not letting your despair lead you to the end that befell the miserable Orlando, or to that which is perhaps no less fictitiously related of Aristotle; for then everyone, myself included, would be deprived of the revelation of something as thoroughly hidden as it is sought after. Therefore I beg you to satiate my greed for it as quickly as you can.

SALV. I am at your service. We have arrived at an inquiry as to how the additions and subtractions of the terrestrial whirling and the annual motion might be made now in greater and now in lesser ratios; for it is such a diversity, and nothing else, that may be assigned as a cause for the monthly and annual changes in the size of the tides. I shall next consider three ways in which this ratio of the additions and subtractions of the earth's rotation and the annual motion may be made greater and less.

First, this could be done by the velocity of the annual motion increasing and decreasing while the additions and subtractions made by the diurnal whirling remained constant in magnitude. For since the annual motion is about three times as fast as the diurnal motion, even taking the latter at the equator, then if we were to increase it further, the addition or subtraction of the diurnal motion would make less of an alteration. On the other hand if it were made slower, this same diurnal motion would alter it proportionately more. Thus to add or subtract four degrees of speed when dealing with something which moves with twenty degrees will alter its course less than if the same four degrees were added to or subtracted from something which moved with only ten degrees of speed.

The second way would be by making the additions and subtractions greater or smaller, retaining the annual motion at the same velocity. This is very easy to see, since it is obvious that a velocity of twenty degrees (for instance) will be altered more by the addition or subtraction of ten degrees than by the addition or subtraction of four.

The third manner would be a combination of these two, the annual motion diminishing and the diurnal additions and subtractions increasing.

As you see, it was easy to get this far; yet it was indeed a laborious task for me to discover how such effects could be accomplished in nature. Yet I finally found something that served me admirably. In a way it is almost unbelievable. I mean that it is astonishing and incredible to us, but not to Nature; for she performs with the utmost ease and simplicity things which are even infinitely puzzling to our minds, and what is very difficult for us to comprehend is quite easy for her to perform.

To continue, then: having demonstrated that the proportions between the additions and subtractions of the whirling on the one hand and the annual motion on the other may be made greater and less in two manners (I say two, because the third is a composite of the others), I add now that Nature does make use of both; and I add further that if she made use of but one of them, then one of the two periodic alterations of the tide would necessarily be removed. The monthly periodic changes would cease if there were no variation due to the annual motion, and if the additions and subtractions of the diurnal rotation were kept always equal, then the annual periodic alterations would be missing.

SAGR. Then do the monthly alterations of the tides depend upon changes in the annual motion of the earth? And the annual alterations in the ebb and flow are derived from the additions and subtractions of the diurnal rotation? Now I am more confused than ever, and farther from any hope of being able to comprehend how this complication comes about, more intricate to my mind than the Gordian knot. I envy Simplicio, from whose silence I deduce that he understands everything and is free from the confusion that beclouds my imagination. **SIMP**. I really believe that you are confused, Sagredo, and I also think I know the cause of your confusion. In my opinion this originates from your understanding a part of what Salviati has set forth, and not understanding another part. And you are also correct about my not being confused at all, though not for the reason you suppose; that is, that I understand the whole thing. Quite the contrary; I understand nothing whatever of it, and confusion lies in the multiplicity of things -- not in nothing.

SAGR. You see, Salviati, how the checkrein that has been applied to Simplicio in the past sessions has gentled him, and changed him from a skittish colt into an ambling nag.

But please, without more delay, put an end to this suspense for both of us.

SALV. I shall do my best to overcome my obscure way of expressing myself, and the sharpness of your wits will fill up the dark places.

There are two events whose causes we must investigate; the first concerns the variation which occurs in the tides over a monthly period, and the other belongs to the annual period. We shall speak first of the monthly, and then deal with the annual; and we must first resolve the whole according to the axioms and hypotheses already established, without introducing any innovations either from astronomy or from the universe to help out the tides. We shall demonstrate that the causes for all the various events perceived in the tides reside in things previously recognized and accepted as unquestionably true. Thus I say that one true, natural, and even necessary thing is that a single movable body made to rotate by a single motive force will take a longer time to complete its circuit along a greater circle than along a lesser circle. This is a truth accepted by all, and in agreement with experiments, of which we may adduce a few.

In order to regulate the time in wheel clocks, especially large ones, the builders fit them with a certain stick which is free to swing horizontally. At its ends they hang leaden weights, and when the clock goes too slowly, they can render its vibrations more frequent merely by moving these weights somewhat toward the center of the stick. On the other hand, in order to retard the vibrations, it suffices to draw these same weights out toward the ends, since the oscillations are thus made more slowly and in consequence the hour intervals are prolonged. Here the motive force is constant --the counterpoise-- and the moving bodies are the same weights; but their vibrations are more frequent when they are closer to the center; that is, when they are moving along smaller circles.

Let equal weights be suspended from unequal cords, removed from the perpendicular, and set free. We shall see the weights on the shorter cords make their vibrations in shorter times, being things that move in lesser circles. Again, attach such a weight to a cord passed through a staple fastened to the ceiling, and hold the other end of the cord in your hand. Having started the hanging weight moving, pull the end of the cord which you have in your hand so that the weight rises while it is making its oscillations. You will see the frequency of its vibrations increase as it rises, since it is going continually along smaller circles.

And here I want you to notice two details which deserve ~ attention. One is that the vibrations of such a pendulum are made so rigorously according to definite times, that it is quite impossible to make them adopt other periods except by lengthening or shortening the cord. Of this you may readily make sure by experiment, tying a rock to a string and holding the end in your hand. No matter how you try, you can never succeed in making it go back and forth except in one definite time, unless you lengthen or shorten the string; you will see that it is absolutely impossible.

The other particular is truly remarkable; it is that the same pendulum makes its oscillations with the same frequency, or very little different -- almost imperceptibly-- whether these are made through large arcs or very small ones along a given circumference. I mean that if we remove the pendulum from the perpendicular just one, two, or three degrees, or on the

other hand seventy degrees or eighty degrees, or even up to a whole quadrant, it will make its vibrations when it is set free with the same frequency in either case; in the first, where it must move only through an arc of four or six degrees, and in the second where it must pass through an arc of one hundred sixty degrees or more. This is seen more plainly by suspending two equal weights from two threads of equal length, and then removing one just a small distance from the perpendicular and the other one a very long way. Both, when set at liberty, will go back and forth in the same times, one by small arcs and the other by very large ones.

From this follows the solution of a very beautiful problem, which is this: Given a quarter of a circle shall draw it here in a little diagram on the ground -- which shall be AB here, vertical to the horizon so that it extends in the plane touching at the point B; take an arc made of a very smooth and polished concave hoop bending along the curvature of the circumference ADB, so that a well-rounded and smooth ball can run freely in it (the rim of a sieve is well suited for this experiment). Now, say that wherever you place the ball, whether near to or far from the ultimate limit B -- placing it at the point C, or at D, or at E-- and let it go, it will arrive at the point B in equal times (or insensibly different), whether it leaves from C or D or E or from any other point you like; a truly remarkable phenomenon. Now add another, no less beautiful than the last. This is that along all chords drawn from the point B to points C, D, E, or any other point (taken not only in the quadrant BA, but in the whole circumference of the entire circle), the same movable body will descend in absolutely equal times. Thus, in the same time which it takes to descend along the whole diameter erected perpendicular to the point B, it will also descend along the chord BC, even when that subtends but a single degree or yet a smaller arc.

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And one more marvel: The motions of bodies falling along the arcs of the quadrant AB are made in shorter times than those made along the chords of the same arcs, so that the fastest motion, made in the shortest time, by a movable body going from the point A to the point B will be along the circumference AOB and will not be that which is made along the straight line AB, although that is the shortest of all the lines which can be drawn between the points A and B. Also, take any point in that same arc (let it be, for instance, the point O), and draw two chords AO and OB; then the moving body leaving from the point A will get to Bin less time going along the two chords AO and OB than going along the single chord AB. The shortest time of all will be that of its fall along the arc AOB, and similar properties are to be understood as holding for all lesser arcs taken upward from the lowest limit B.

SAGR. Enough; no more; you are confusing me so with marvels, and are distracting my mind in so many directions, that I fear only a small part of it will remain free and clear for me to apply to the main subject we are dealing with -- which, I regret to say, is too obscure and difficult as it is. I beg you, as a favor to me, that when we have finished with the theory of the tides there shall be other days when you will again honor this house of mine and of yours, to discuss the many other problems that have been left dangling. Perhaps they will be no less interesting and elegant than these which we have been treating in the days just past, and which ought to be finished today.

SALV. I shall be at your disposal, though we shall have to have more than one or two sessions if, in addition to the questions reserved to be separately dealt with, we wish to add the many that pertain both to local motion and to the motions natural to projectiles -- subjects dealt with at length by our Lincean Academician.

Getting back to our original purpose, we were explaining that for things moved circularly by some motive force which is kept continually the same, the times of circulation are preestablished and determined, and impossible to lengthen or shorten. Having given examples of this and brought forth sensible experiments which we can perform, we may affirm the same to be true of our experience of the planetary movements in the heavens, for which the same rule is seen to hold: Those which move in the larger circles consume the longer times in passing through them. We have the most ready observations of this from the satellites of Jupiter, which make their revolutions in short times. So there is no question that if, for example, the moon, continuing to be moved by the same motive force, were drawn little by little into smaller circles, it would acquire a tendency to shorten the times of its periods, in agreement with that pendulum which in the course of its vibrations had its cord shortened by us, reducing the radius of the circumference traversed. Now this example which I

gave you concerning the moon actually takes place and is verified in fact. Let us remember that we had already concluded with Copernicus that it is not possible to separate the moon from the earth, about which it unquestionably moves in a month. Let us likewise remember that the terrestrial globe, always accompanied by the moon, goes along the circumference of its orbit about the sun in one year, in which time the moon revolves around the earth almost thirteen times. From this revolution it follows that the moon is sometimes close to the sun (that is, when it is between the sun and the earth), and sometimes more distant (when the earth lies between the moon and the sun). It is close, in a word, at the time of conjunction and new moon, it is distant at full moon and opposition, and its greatest distance differs from its closest approach by as much as the diameter of the lunar orbit.

Now if it is true that the force which moves the earth and the moon around the sun always retains the same strength, and if it is true that the same moving body moved by the same force but in unequal circles passes over similar arcs of smaller circles in shorter times, then it must necessarily be said that the moon when at its least distance from the sun (that is, at conjunction) passes through greater arcs of the earth's orbit than when it is at its greatest distance (that is, at opposition and full moon). And it is necessary also that the earth should share in this irregularity of the moon. For if we imagine a straight line from the center of the sun to the center of the terrestrial globe, including also the moon's orbit, this will be the radius of the orbit in which the earth would move uniformly if it were alone. But if we locate there also another body carried by the earth, putting this at one time between the earth and the sun and at another time beyond the earth at its greatest distance from the sun, then in this second case the common motion of both along the circumference of the earth's orbit would, because of the greater distance of the moon, have to be somewhat slower than in the other case when the moon is between the earth and the sun, at its lesser distance. So that what happens in this matter is just what happened to the rate of the clock, the moon representing to us that weight which is attached now farther from the center, in order to make the vibrations of the stick less frequent, and now closer, in order to speed them up.

From this it may be clear that the annual movement of the earth in its orbit along the ecliptic is not uniform, and that its irregularity derives from the moon and has its periods and restorations monthly. Now it has already been decided that the monthly and annual periodic alterations of the tides could derive from no other cause than from varying ratios between the annual motion and the additions to it and subtractions from it of the diurnal rotation; and that such alterations might be made in two ways; that is, by altering the annual motion and keeping fixed the magnitudes of the additions, or by changing the size of these and keeping the annual motion uniform. We have now detected the first of these two ways, based upon the unevenness of the annual motion; it depends upon the moon, and has its period monthly. Thus it is necessary that for this reason the tides should have a monthly period within which they become greater and smaller.

Now you see how the cause of the monthly period resides in the annual motion, and at the same time you see what the moon has to do with this affair, and how it plays a role without having anything to do with oceans or with waters.

SAGR. If a very high tower were shown to someone who had no knowledge of any kind of staircase, and he were asked whether he dared to scale such a supreme height, I believe he would surely say no, failing to understand that it could be done in any way except by flying. But being shown a stone no more than half a yard high and asked whether he thought he could climb up on it, he would answer yes, I am sure; nor would he deny that he could easily climb up not once, but ten, twenty, or a hundred times. Hence if he were shown the stairs by which one might just as easily arrive at the place he had adjudged impossible to reach, I believe he would laugh at himself and confess his lack of imagination.

You, Salviati, have guided me step by step so gently that r I am astonished to find I have arrived with so little effort at a height which I believed impossible to attain. It is certainly true that the staircase was so dark that I was not aware of my approach to or arrival at the summit, until I had come out into the bright open air and discovered a great sea and a broad plain. And just as climbing step by r step is no trouble, so one by one your propositions appeared so clear to me, little or nothing new being added, that I thought little or nothing was being gained. So much the more is my wonder at the unexpected outcome of this argument, which has led me to a comprehension of things I believed inexplicable.

Just one difficulty remains from which I desire to be freed. If the movement of the earth around the zodiac in company with the moon is irregular, such an irregularity ought to have been observed and noticed by astronomers, but I do not

know that this has occurred. Since you are better informed on these matters than I am, resolve this question for me and tell me what the facts are.

SALV. Your doubt is very reasonable, and in response to the objection I say that although astronomy has made great progress over the course of the centuries in investigating the arrangement and movements of the heavenly bodies, it has not thereby arrived at such a state that there are not I many things still remaining undecided, and perhaps still more which remain unknown. It is likely that the first observers of the sky recognized nothing but a general motion of all the stars -- the diurnal motion-- but I think it was not long before they discovered that the moon is inconstant about keeping company with the other stars. Years would have passed before they had distinguished all the planets, however. In particular, I believe that Saturn, on account of Its slowness, and Mercury, because of being rarely seen, were the last objects to be recognized as vagrant and wandering. Many more years probably passed before the stoppings and retrograde motions of the three outer planets were observed, and their approaches and retreats from the earth, which occasioned the need to introduce eccentrics and epicycles-- things unknown even to Aristotle, who makes no mention of them. How long did Mercury and Venus, with their remarkable phenomena, keep astronomers in suspended judgment about their true locations, to mention nothing else? Thus even the ordering of the world bodies and the integral structure of that part of the universe recognized by us was in doubt up to the time of Copernicus, who finally supplied the true arrangement and the true system according to which these parts are ordered, so that we are certain that Mercury, Venus, and the other planets revolve about the sun and that the moon revolves around the earth. But we cannot yet determine surely the law of revolution and the structure of the orbit of each planet (the study ordinarily called planetary theory); witness to this fact is Mars, which has caused modern astronomers so much distress. Numerous theories have also been applied to the moon itself since the time when Copernicus first greatly altered Ptolemy's theory.

Now to get down to our particular point; that is, to the apparent motions of the sun and moon. In the former there has been observed a certain great irregularity, as a result of which it passes the two semicircles of the ecliptic (divided by the equinoctial points) in very different times, consuming about nine days more in passing over one half than the other; a difference which is, as you see, very conspicuous. It has not yet been observed whether the sun preserves a regular motion in passing through very small arcs, as for example those of each sign of the zodiac, or whether it goes at a pace now somewhat faster and now slower, as would necessarily follow if the annual motion belongs only apparently to the sun and really to the earth in company of the moon. Perhaps this has not even been looked into.

As to the moon, its cycles have been investigated principally in the interest of eclipses, for which it suffices to have an exact knowledge of its motion around the earth. The progress of the moon through particular arcs of the zodiac has accordingly not been investigated in thoroughgoing detail. Therefore the fact that there is no obvious irregularity is insufficient to cast doubt upon the possibility that the earth and the moon are somewhat accelerated at new moon and retarded at full moon in traveling through the zodiac; that is, in going along the circumference of the earth's orbit. This comes about for two reasons; first, that the effect has not been looked for, and second, that it cannot be very large.

Nor is there any need for the irregularity to be very large in order to produce the effect that is seen in the alterations of the size of the tides. For not only the changes, but the tides themselves, are small with respect to the magnitude of the bodies in which they occur, though with respect to us and to our smallness they seem to be great things. Adding or deducting one degree of speed where there are naturally seven hundred or a thousand cannot be called a large change, either in what confers it or in what receives it; and the water of our sea, carried by the diurnal whirling, travels about seven hundred miles per hour. This is the motion common to it and to the earth, and therefore imperceptible to us. The motion which is made sensible to us in currents is not even one mile per hour (I am speaking of the open sea, and not of straits), and it is this that alters the great, natural primary motion.

Still, such a change is considerable with respect to us and to our ships. A vessel that can make, say, three miles per hour in quiet water under the power of its oars, will have its travel doubled by such a current favoring it instead of opposing it. This is a very notable difference in the motion of the boat, though it is quite small in the movement of the sea, which is changed by only one seven-hundredth. I say the same of its rising and falling one, two, or three feet-- scarcely four or five feet even at the extremity of a basin two thousand or more miles long, where its depth is hundreds of feet. Such a change

is much less than if, in one of the barges bringing sweet water to us, this water should rise in the prow by the thickness of a leaf at an arrest of the barge. From this I conclude that very small alterations with respect to the immense size and extreme speed of the oceans would be sufficient to make great changes in them in relation to the minuteness of ourselves and our phenomena.

SAGR. I am fully satisfied as to this part. It remains for you to explain to us how these additions and subtractions deriving from the diurnal whirling are increased or diminished, upon which alterations you hinted would depend the annual period of growth and diminution in the tides.

SALV. I shall use all my resources to make myself understood, but the difficulty of the phenomena themselves and the great abstractness of mind needed to understand them intimidate me.

The irregularity of the additions and subtractions which the diurnal rotation makes upon the annual motion depends upon the tilting of its axis to the plane of the earth's orbit, or ecliptic. By this tilting, the equator crosses the ecliptic and is inclined and oblique to it with the same slope as that of the axis. The magnitude of the additions amounts to as much as the entire diameter of the equator when the center of the earth is at the solstitial points, but outside of those it amounts to less and less according as the center approaches the equinoctial points, where such additions are least of all. This is the whole story, but it is wrapped in the obscurity which you perceive.

SAGR. Rather in that which I do not perceive, since so far I do not understand a thing.

SALV. That is just what I expected; nevertheless, we shall see whether the drawing of a little diagram will not shed some light on it. It would be better to represent this effect by means of solid bodies than by a mere picture; however, we may get some assistance from perspective and foreshortening. So let us show, as before, the circumference of the earth's orbit, the point A being supposed to be at one of the solstices and the diameter AP being the common section of the solstitial colure and the plane of the earth's orbit, or ecliptic. Suppose the center of the terrestrial globe to be located at this point A; its axis, CAB, tilted to the plane of the earth's orbit, falls in the plane of the said colure, which passes through the axes of both equator and ecliptic. To avoid confusion, we shall show only the equatorial circle, indicating this with the letters DGEF, whose common section with the plane of the earth's orbit will be the line DE, so that one half of the equator, marked DFE, will be below the plane of the earth's orbit, and the other half, DGE, will be above it.

- Figure 31

It is now supposed that the revolution of the equator is in the order of the points D, G, E, F, and that the motion of the center is toward E. The center of the earth being at A, its axis CB (which is perpendicular to the equatorial diameter DE) falls as we said in the solstitial colure, the common section of this with the earth's orbit being the diameter PA; hence this line PA will be perpendicular to DE, because the colure is perpendicular to the earth's orbit. Therefore DE will be tangent to the earth's orbit at the point A, so that in this position the motion of the center along the arc AE, which amounts to one degree per day, would vary but little; it would even be as if it were along the tangent DAE. And since the diurnal rotation, carrying the point D through G to E, is increased over the motion of the center (which moves practically along this same line DE) by as much as the whole diameter DE, while on the other hand the other semicircle EFD is diminished by the same amount in its motion, the additions and subtractions at this point (that is, at the time of the solstice) will be measured by the entire diameter DE.

Next we shall see whether they are of the same magnitude at the times of the equinoxes. Transporting the center of the earth to the point I, one quadrant away from the point A, let us take the same equator GEFD, its common section DE with the ecliptic, and its axis CB at the same tilt. Now the tangent to the ecliptic at the point I will no longer be DE, but a different one, cutting this at right angles. This will be marked HIL, in the direction of which will be the motion of the center I, proceeding along the circumference of the earth's orbit. Now in this situation the additions and subtractions are not measured anymore by the diameter DE, as they were at first, f9rsince this diameter does not extend along the line of the annual motion HL, but rather cuts it at right angles, D and E add and subtract nothing.

The additions and subtractions must now be taken along that diameter which falls in the plane perpendicular to that of the earth's orbit and cutting it in the line HL let this be the diameter GF. The additive motion will then be made by the point G along the semicircle GEF, and the subtractive motion will be the balance, along the other semicircle FDG. Now this diameter being not in the same line as the annual motion, HL, but cutting it as is seen in the point I (with the point G being elevated above and F depressed below the plane of the earth's orbit), the additions and subtractions are not determined by its entire length. Rather, they must be that fraction of it taken between the parts of the line HL which are cut off between the perpendiculars drawn upon it from the points G and F, which would be two lines GS and FV: Hence the measure of the additions is the line SV, and this is less than GF or DE, which was the measure of the additions at the solstice A.

According, then, to the placement of the center of the earth at any other point of the quadrant AI, we draw the tangent at such a point and drop perpendiculars upon it from the ends of the equatorial diameter determined by the plane through this tangent vertical to the plane of the ecliptic; and such apart of this tangent, which will be always less toward the equinoxes and greater toward the solstices, will give us the magnitudes of the additions and subtractions. Then as to how much the least additions differ from the greatest, this is easy to determine; between these there is the same variation as between the whole axis (or diameter) of the globe and that part of it which lies between the polar circles. This is less than the whole diameter by one-twelfth, approximately, assuming that the additions and subtractions are made at the equator; in other latitudes they are less in proportion as their diameters are diminished.

That is all I can tell you about the matter, and perhaps it is as much as can be comprehended within our knowledge-- which, as is well known, can be only of such conclusions as are fixed and constant. Such are the three general periods of the tides, since these depend upon invariable causes which are unified and eternal. But with these primary and universal causes there are mixed others which, though secondary and particular, are capable of making great alterations; and these secondary causes are partly variable and not subject to observations (the changes due to winds, for example), and partly, though determinate and fixed, are not observed because of their complication. Such are the lengths of the sea basins, their various orientations in one direction or another, and the many and various depths of the waters. Who could possibly formulate a complete account of these except perhaps after very lengthy observations and reliable reports? Without this, what could serve as a sound basis for hypotheses and assumptions on the part of anyone who, from such a combination, wished to furnish adequate reasons for all the phenomena? And, I might add, for the anomalies and particular irregularities that can be perceived in the movements of the waters?

I am content to have noticed that incidental causes do exist in nature, and that they are capable of producing many alterations; I shall leave their minute observation to those who frequent the various oceans. I merely call to your attention, in bringing this conversation of ours to a close, that the precise durations of the ebbing and flowing are changed not only by the lengths and depths of the basins, but I believe that noteworthy variations are also introduced by the juncture of various stretches of ocean which differ in size and in situation or, let us say, in orientation. Such a contrast occurs right here in the Adriatic Gulf, which is much smaller than the rest of the Mediterranean and is placed at such a different orientation that whereas the latter has its closed end in the eastern part at the shores of Syria, the former is closed at its western part. And since it is at the extremities that by far the greatest tides occur-- indeed, nowhere else are there very great risings and fallings-- it may very well be that the times of flood at Venice occur during the ebbings of the other sea. The Mediterranean, being much larger and extending more directly from west to east, in a certain sense dominates the Adriatic. Hence it would not be surprising if the effects that depend upon the primary causes were not verified in the Adriatic at the appointed times and corresponding to the proper periods, as well at least as they would be in the rest of the Mediterranean. But this matter would require long observations which I have not made in the past, nor shall I be able to make them in the future.

SAGR. It seems to me that you have done a great deal by opening the first portal to such lofty speculations. In your first general proposition, which seems to me to admit of no refutation, you have explained very persuasively why it would be impossible for the observed movements to take place in the ordinary course of nature if the basins containing the waters of the seas were standing still, and that on the other hand such alterations of the seas would necessarily follow if one assumed the movements attributed by Copernicus to the terrestrial globe for quite other reasons. If you had given us no more, this alone seems to me to excel by such a large margin the trivialities which others have put forth that just to think of those once more makes me ill. And I am much astonished that among men of sublime intellect, of whom there have been plenty, none have been struck by the incompatibility between the reciprocating motion of the contained waters and the immobility of the containing vessels, a contradiction which now seems so obvious to me.

SALV. What is more to be wondered at, once it had occurred to the minds of some to refer the cause of the tides to the motion of the earth (which showed unusual perspicacity on the part of these men), is that in seizing at this matter they should have caught onto nothing. But this was because they did not notice that a simple and uniform motion, such as the simple diurnal motion of the terrestrial globe for instance, does not suffice, and that an uneven motion is required, now

accelerated and now retarded. For if the motion of the vessels were uniform, the contained waters would become habituated to it and would never make any mutations.

Likewise it is completely idle to say (as is attributed to one of the ancient mathematicians) that the tides are caused by the conflict arising between the motion of the earth and the motion of the lunar sphere, not only because it is neither obvious nor has it been explained how this must follow, but because its glaring falsity is revealed by the rotation of the earth being not contrary to the motion of the moon, but in the same direction. Thus everything that has been previously conjectured by others seems to me completely invalid. But among all the great men who have philosophized about this remarkable effect, I am more astonished at Kepler than at any other. Despite his open and acute mind, and though he has at his fingertips the motions attributed to the earth, he has nevertheless lent his ear and his assent to the moon's dominion over the waters, to occult properties, and to such puerilities.

SAGR. It is my guess that what has happened to these more reflective men is what is happening at present to me; namely, inability to understand the interrelation of the three periods, annual, monthly, and diurnal, and how their causes may seem to depend upon the sun and the moon without either of these having anything to do with the water itself. This matter, for a full understanding of which I need a longer and more concentrated application of my mind, is still obscure to me because of its novelty and its difficulty. But I do not despair of mastering it by going back over it by myself, in solitude and silence, and ruminating on what remains undigested in my mind.

In the conversations of these four days we have, then, strong evidences in favor of the Copernican system, among which three have been shown to be very convincing-- those taken from the stoppings and retrograde motions of the planets, and their approaches toward and recessions from the earth; second, from the revolution of the sun upon itself, and from what is to be observed in the sunspots; and third, from the ebbing and flowing of the ocean tides.

SALV. To these there may perhaps be added a fourth, and maybe even a fifth. The fourth, I mean, may come from the fixed stars, since by extremely accurate observations of these there may be discovered those minimal changes that Copernicus took to be imperceptible. And at present there is transpiring a fifth novelty from which the mobility of the earth might be argued. This is being revealed most perspicuously by the illustrious Caesar Marsili, of a most noble family at Bologna, and a Lincean Academician. He explains in a very learned manuscript that he has observed a continual change, though a very slow one, in the meridian line. I have recently seen this treatise, and it has much astonished me. I hope that he will make it available to all students of the marvels of nature.

SAGR. This is not the first time that I have heard mention of the subtle learning of this gentleman, who has shown himself to be the zealous protector of all men of science and letters. If this or any other of his works is made public, we may be sure in advance that it will become famous.

SALV. Now, since it is time to put an end to our discourses, it remains for me to beg you that if later, in going over the things that I have brought out, you should meet with any difficulty or any question not completely resolved, you will excuse my deficiency because of the novelty of the concept and the limitations of my abilities; then because of the magnitude of the subject; and finally because I do not claim and have not claimed from others that assent which I myself do not give to this invention, which may very easily turn out to be a most foolish hallucination and a majestic paradox.

To you, Sagredo, though during my arguments you have shown yourself satisfied with some of my ideas and have approved them highly, I say that I take this to have arisen partly from their novelty rather than from their certainty, and even more from your courteous wish to afford me by your assent that pleasure which one naturally feels at the approbation and praise of what is one's own. And as f you have obligated me to you by your urbanity, so Simplicio has pleased me by his ingenuity. Indeed, I have become very fond of him for his constancy in sustaining so forcibly and so undauntedly the doctrines of his master. And I thank you, Sagredo, for your most courteous motivation, just as I ask pardon of Simplicio if I have offended him sometimes with my too heated and opinionated speech. Be sure that in this I have not been moved by any ulterior purpose, but only by that of giving you every opportunity to introduce lofty thoughts, that I might be the better informed.

SIMP. You need not make any excuses; they are superfluous, and especially so to me, who, being accustomed to public debates, have heard disputants countless times not merely grow angry and get excited at each other, but even break out into insulting speech and sometimes come very close to blows.

As to the discourses we have held, and especially this last one concerning the reasons for the ebbing and flowing of the ocean, I am really not entirely convinced; but from such feeble ideas of the matter as I have formed, I admit that your thoughts seem to me more ingenious than many others I have heard. I do not therefore consider them true and conclusive; indeed, keeping always before my mind's eye a most solid doctrine that I once heard from a most eminent and learned person, and before which one must fall silent, I know that if asked whether God in His infinite power and wisdom could have conferred upon the watery element its observed reciprocating motion using some other means than moving its containing vessels, both of you would reply that He could have, and that He would have known how to do this in many ways which are unthinkable to our minds. From this I forthwith conclude that, this being so, it would be excessive boldness for anyone to limit and restrict the Divine power and wisdom to some particular fancy of his own.

SALV. An admirable and angelic doctrine, and well in accord with another one, also Divine, which, while it grants to us the right to argue about the constitution of the universe (perhaps in order that the working of the human mind shall not be curtailed or made lazy) adds that we cannot discover the work of His hands. Let us, then, exercise these activities permitted to us and ordained by God, that we may recognize and thereby so much the more admire His greatness, however much less fit we may find ourselves to penetrate the profound depths of His infinite wisdom.

SAGR. And let this be the final conclusion of our four days' arguments, after which if Salviati should desire to take some interval of rest, our continuing curiosity must grant that much to him. But this is on condition that when it is more convenient for him, he will remain and satisfy our desires-- mine in particular-- regarding the problems set aside and noted down by me to submit to him at one or two further sessions, in accordance with our agreement. Above all, I shall be waiting impatiently to hear the elements of our Academician's new science of natural and constrained local motions.

Meanwhile, according to our custom, let us go and enjoy an hour of refreshment in the gondola that awaits us.

END OF THE FOURTH AND FINAL DAY

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