# Descartes on Galileo, 11 Oct. 1638

**I shall commence this letter by my observations about Galileo's book. I find generally that he philosophizes much better than ordinary, in that he avoids as best he can the errors of the scholastics, and undertakes to examine physical matters by mathematical reasonings. In this I accord with him entirely and I hold that there is no better way to find the truth. But he seems to me very faulty in continually making digressions and never stopping to explain [*explicandae*] completely any matter, which shows that he has not examined things in order, and that without having considered the first causes of nature he has only sought the reasons of some particular effects, and thus he built without foundation [*fundamento*].**

# Descartes on Days One and Two

**p. 88. His experiment to know if light is transmitted in an instant is useless, since eclipses of the moon, related so closely to calculations made of them, prove this incomparably better than anything that could be tested on earth.**

**p. 113. He says rightly that bodies descend more unequally fast in water than in air, but he says nothing at all about the cause, and he is wrong (p. 114) in saying that water does not at all resist being divided.**

**p. 116-17. Everything he says about the speeds of bodies descending in the void etc. is built without foundation [*nullo fundamento*], for first he should have determined what weight [*gravitas*] is, and if he had known the truth, he would have known that it is nothing in the void.**

# Descartes on Day Three

**pp. 197-8. He supposes that the speeds in falling weights always increase equally, which I formerly believed like him, but I now believe I can prove that it is not true.**

**p. 205. He supposes also that the degrees of speed of the same body over different planes are equal when the elevations are equal, which he does not prove and is not exactly true, and since everything that ensues depends on those two assumptions, one can say it is entirely built in the air. For the rest, he seems not to have written his third dialogue except to give a reason why all descents and returns of the same cord [of a pendulum, through different arcs of a circle] are equal to one another, and yet he does not do this, but concludes only that weights descend faster along the arc of a circle than along the chord of the same arc, which also he has been unable to deduce exactly from his assumptions.**

# Descartes on Day Four

**p. 268. He adds another assumption to the preceding [two], which is no more true; namely, that bodies thrown in air go uniformly fast along the horizontal, but that in falling their speeds increase in the squared ratio [sic] of the distance. Now, given this, it is very easy to conclude that the movement of bodies thrown ought to follow a parabolic line; but his hypotheses being false, his conclusion can well be very far from the truth.**

**p. 296. It is to be noted that he takes the converse of his proposition without proving or explaining it, that is, if the shot fired horizontally from B toward E follows the parabola BD, the shot fired obliquely following the line DE must follow the same parabola DB, which indeed follows from his assumptions. But he seems not to have dared to explain these from fear their falsity would be too evident. Yet he makes use only of this converse in all the rest of his fourth discourse, which he seems to have written only to explain the force of cannon shots fired at different elevations. Moreover, it is to be noted that in setting forth his assumptions he excludes artillery in order to make them more easily accepted, and yet toward the end it is mainly to artillery that he applies his conclusion. This is to say, in a word, that all is built in the air.**

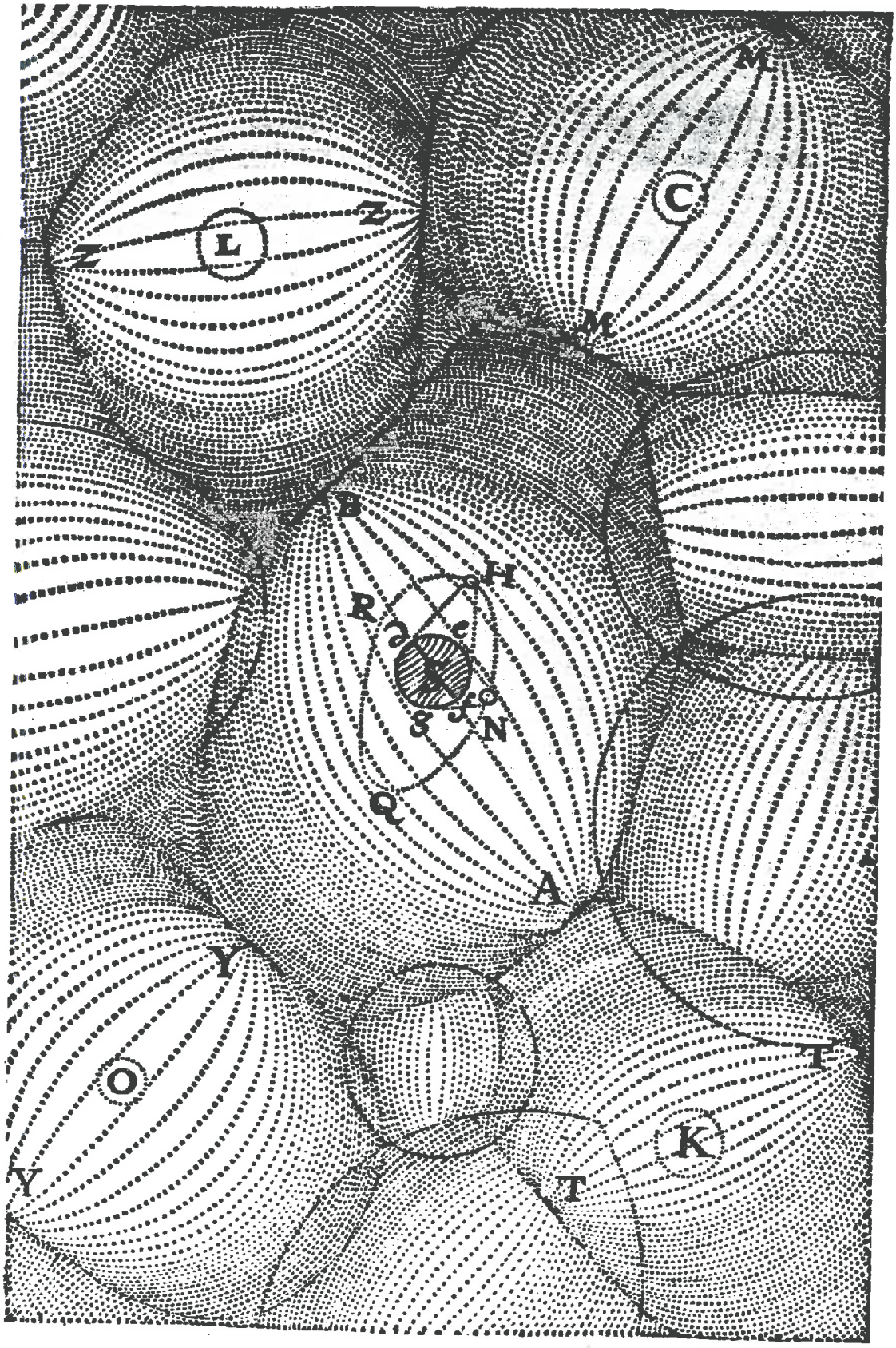
# Descartes on Fermat on Galileo

**… What Galileo says that falling bodies pass through all degrees of speed, I do not at all think that happens ordinarily, though it is not impossible that it sometimes happens. And there is error in the argument used by M. F[ermat] to refute this, in that he says that "speed is to be acquired either in the first instant or in some determined time;" for neither the one nor the other is true…. In sum everything that he says about degrees of speed of movement can be said in the same way about degrees of length of triangle ABC, and yet I do not believe ~~that he~~ wants to deny that between point A and line BC there are not all the lengths that are less than BC.**

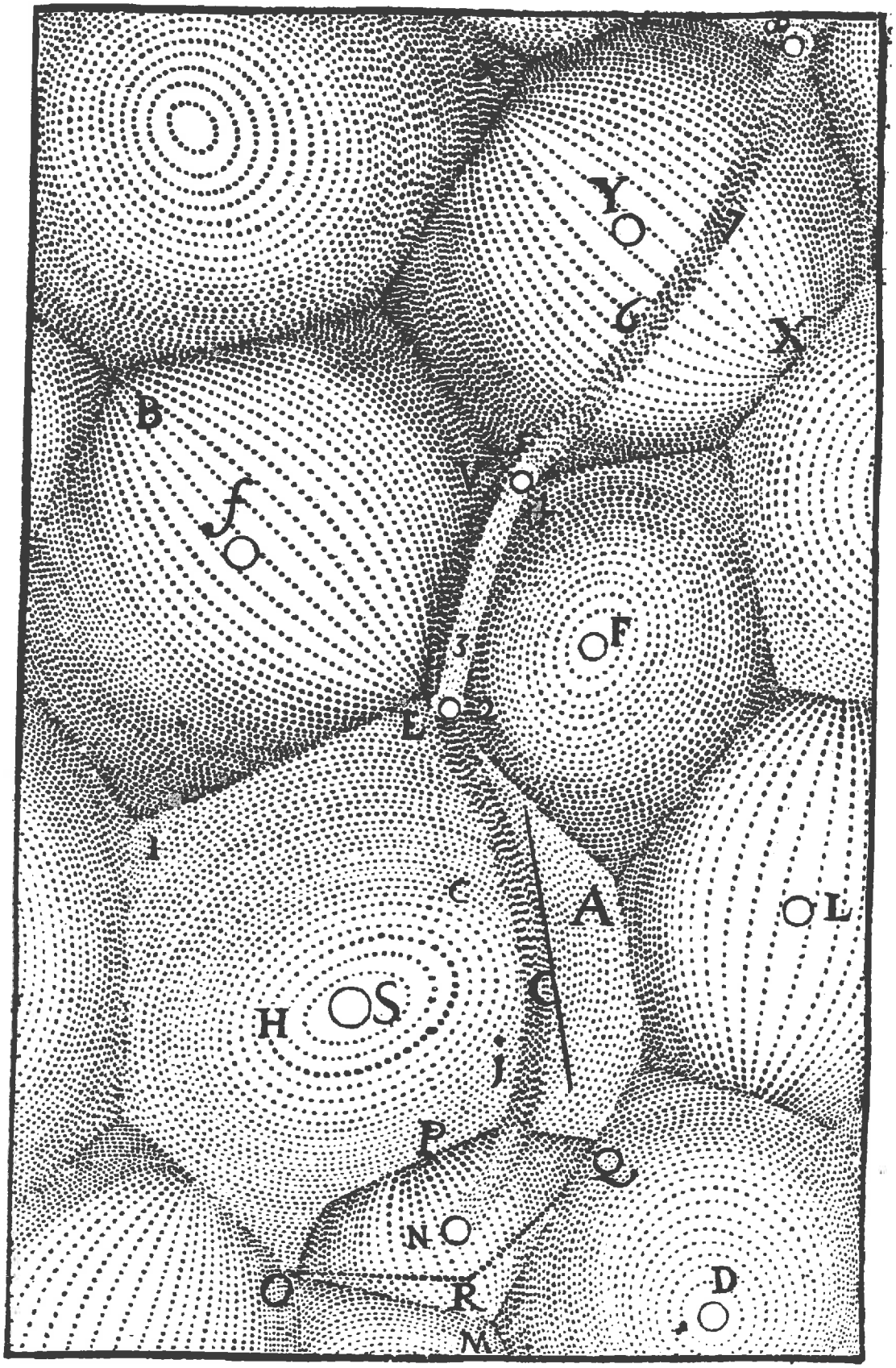
**And for refutation of Galileo's opinion concerning movements on inclined planes, M. F[ermat] is mistaken in that he founds his argument on tendency of weights toward the center of earth, which he imagines as a point, and Galileo assumes that they descend along parallel lines.**

## III,30. That all the Planets are carried around the Sun by the heaven.

**Now that we have, by this reasoning, removed any possible doubt about the motion of the Earth, let us assume that the matter of the heaven, in which the planets are situated, unceasingly revolves, like a vortex having the Sun as its center, and that those of its parts which are close to the Sun move more quickly than those further away; and that all the Planets (among which we {shall from now on} include the Earth) always remain suspended among the same parts of this heavenly matter. For by that alone, and without any other devices, all their phenomena are very easily understood. Thus, if some straws {or other light bodies} are floating in the eddy of a river, where the water doubles back on itself and forms a vortex as it swirls; we can see that it carries them along and makes them move in circles with it. Further, we can often see that some of these straws rotate about their own centers, and that those which are closer to the center of the vortex which contains them complete their circle more rapidly than those which are further away from it. Finally, we see that, although these whirlpools always attempt a circular motion, they practically never describe perfect circles, but sometimes become too great in width or in length, {so that all parts of the circumference which they describe are not equidistant from the center.} Thus we can easily imagine that all the same things happen to the Planets; and this is all we need to explain [*explicantur*] all their remaining phenomena.**




11.1. Descartes's conception of a typical region of the universe, as expounded in Part III of *Principia philosophiae* (1644). Several stars are portrayed, each surrounded by its own vortex.

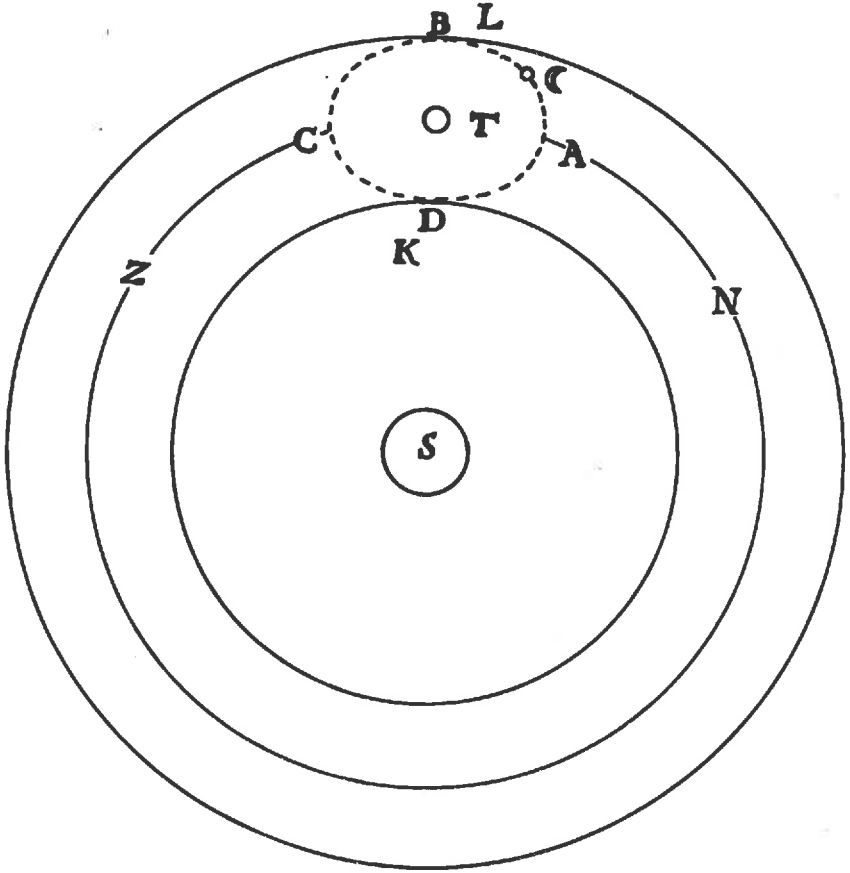



11.2. Diagram to illustrate the path of a typical comet from one vortex to the next, from Part III of Descartes's *Principia philosophiae*.

## III.33. How the Earth is moved around its own center and the Moon around the Earth.

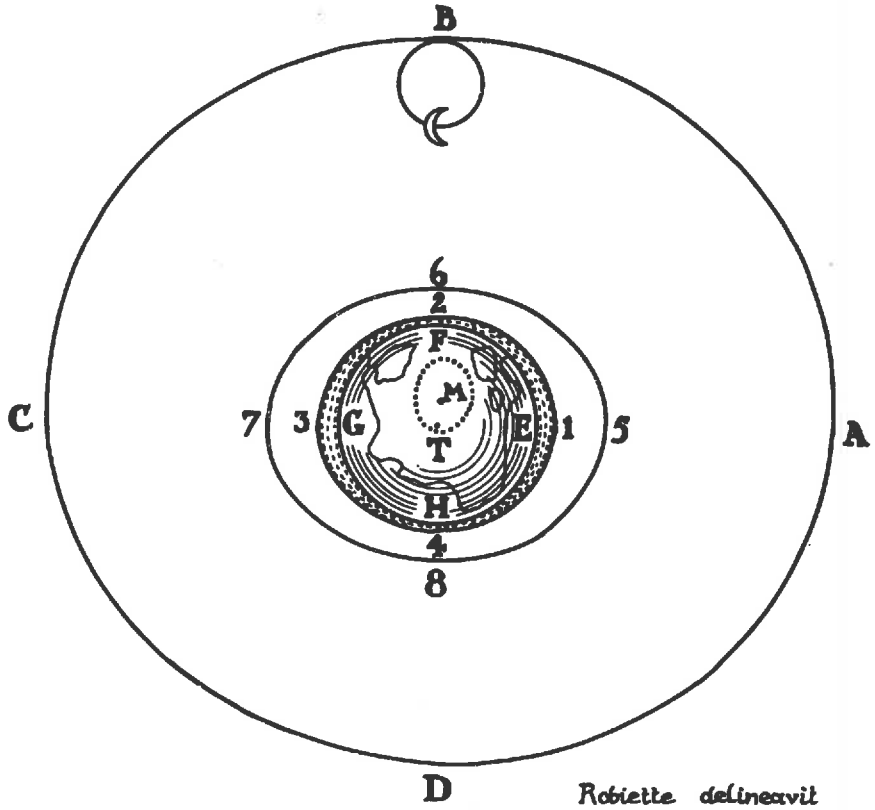
**In addition, in the great vortex which forms a heaven {having the Sun at its center}, there are other smaller ones which we can compare to those I have often seen in eddies of rivers where they {all follow the current of the larger vortex which carries them, and} move in the direction in which it moves. One of these vortices has Jupiter at its center, and moves with it the four satellites which revolve around Jupiter.... Similarly, the vortex which has the Earth at its center carries the Moon around the Earth in the space of a month, while the Earth turns on its axis in the space of twenty-four hours.**

Plate XV




Robiette delineavit

Plate XIX




Robiette delineavit

**III,42-44.** **... And we shall know that we have correctly determined these causes when we observe that we can explain (*explicari*), by their means, not only those phenomena which we have considered up to now, but also everything else about which we have not previously thought.**

**... I wish what I shall write later to be taken only as an hypothesis {which is perhaps very far from the truth}. But, even though these things may be thought to be false, I shall consider that I have achieved a great deal if all the things which are deduced from them are entirely in conformity with the phenomena: for, if this comes about, my hypothesis will be useful to life as if it were true {because we will be able to use it in the same way to dispose natural causes to produce the effects we desire}.**

**Letter to Morin, 13 July 1638.** **... You say 'the phenomena of the heavenly movements can be deduced with no less certainty from the assumption that the earth is stationary than from the assumption that it moves.' I agree readily. ... You say also that there is a vicious circle in proving effects from a cause and then proving the cause by the same effects. I agree: but I do not agree that it is circular to explain effects by a cause, and then prove the cause by the effects: because there is a big difference between *proving* and *explaining*. I should add also that the word 'demonstrate' can be used to signify either, if it is used according to common usage and not in the technical philosophical sense....**

**Finally, you say that nothing is easier than to fit a cause to an effect. It is true that there are many effects to which it is easy to fit many separate causes; but it is not always so easy to fit a single cause to many different effects, unless it is the true cause which produces them.**

# An Approach to Theorizing

1) **To impose constraints on all "explanation" – i.e., on answers to why- and how-questions – to the point that**

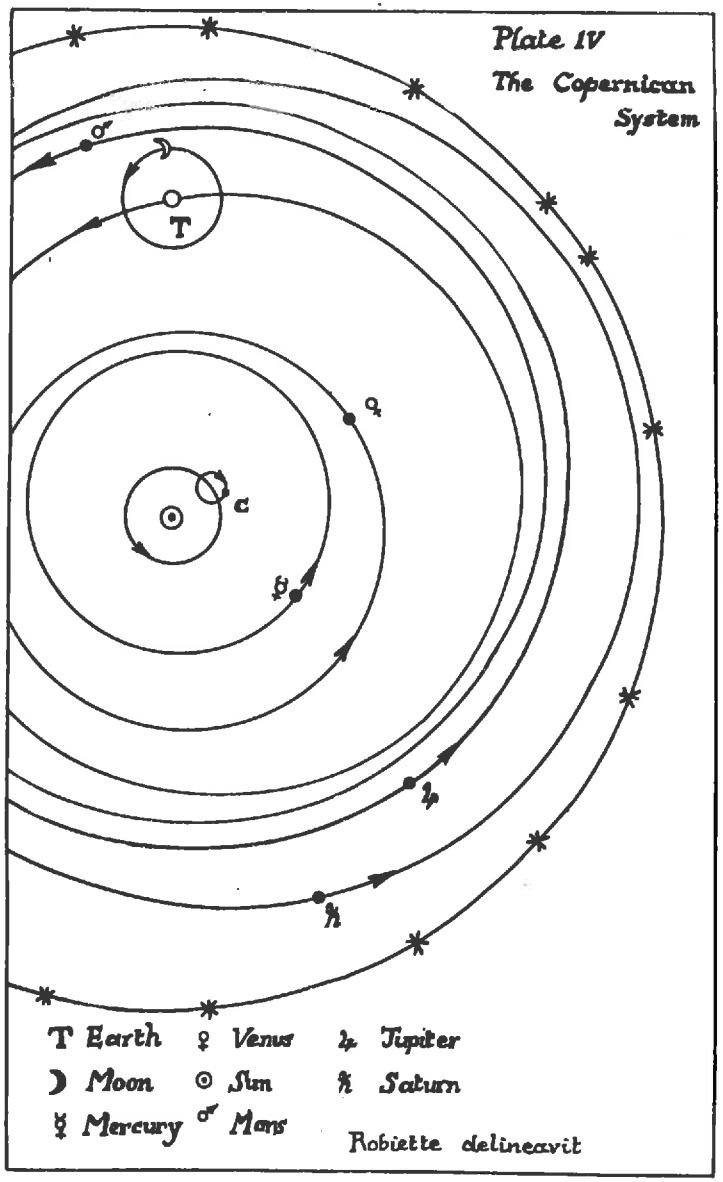
2) **Observed phenomena restrict the range of candidate answers to such questions to the point that**

3) **A demand that the factors invoked in any answer to one such question simultaneously yield answers to a wide range of further questions, suffices to single out one answer, at least in broad outline.**

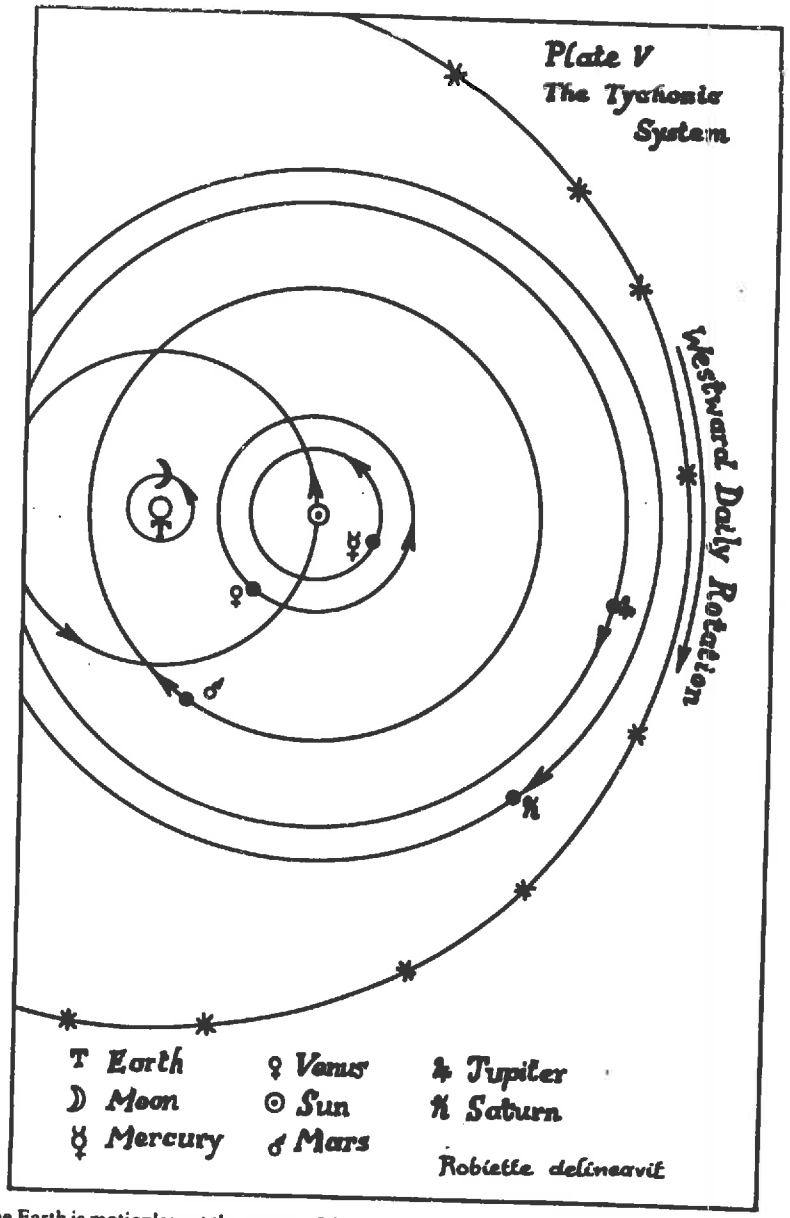
**This is *not* the same as a hypothetico-deductive approach!**

**Descartes is invoking empirical considerations throughout, but he is *not* comparing them with empirical claims deduced from his hypotheses in order to test those hypotheses!**

**A "hypothetico-explanatory" approach?**




The Sun is at the center of the stellar sphere. The Earth rotates once a day from west to east and revolves eastward in a yearly circular orbit with its center at c. c itself moves on a deferent and epicycle system whose center is the Sun. The planets move eastward in circular orbits, the centers of which each move in such a way as to maintain a fixed relationship to c.




The Earth is motionless at the center of the stellar sphere, and the stars, Moon, and Sun move as they do in the Ptolemaic system. The planets, however, move in orbits centered on the moving Sun; Mercury and Venus revolve eastward around the Sun, and the remaining planets revolve westward.

## III,28. That the Earth, properly speaking, is not moved, nor are any of the Planets; although they are carried along by the heaven.

**And it is important to remember here what was said earlier concerning the nature of movement, i.e. that (if we are speaking properly and in accordance with the truth of the matter) it is only the transference of a body from the vicinity of those bodies which are immediately contiguous to it, and considered to be at rest, into the vicinity of others. However, in common usage, all action by which any body travels from one place to another is often called movement; and in this sense of the term it can be said that the same thing is simultaneously moved and not moved, according to the way we diversely determine its location. From this it follows that no movement, in the strict sense, is found in the Earth or even in the other planets; because they are not transported from the vicinity of the parts of the heaven immediately contiguous to them, inasmuch as we consider those parts of the heaven to be at rest. For, to be thus transported, they would have to be simultaneously separated from all {the contiguous parts of the heaven}, which does not happen. However, because the matter of the heaven is fluid, sometimes some of its particles, and sometimes others, move away from the Planet to which they are contiguous, and this by a movement which must be attributed solely to them and not to the Planet: in the same way as the partial transferences of water and air which occur on the earth's surface are usually attributed, not to the earth, but to those portions of water and air which are transported.**

## II,25. What movement properly speaking is

**If, however, we consider what should be understood by movement, according to the truth of the matter rather than in accordance with common usage (in order to attribute a determinate nature to it): we can say that it is *the transference of one part of matter or of one body, from the vicinity of those bodies immediately contiguous to it and considered as at rest, into the vicinity of others.* By *one body*, or *one part of matter*, I here understand everything which is simultaneously transported; even though this may be composed of many parts which have other movements among themselves. I also say that it is a *transference*, not the force or action which transfers, in order to show that this motion is always in the moving body and not in the thing which moves it (because it is not usual to distinguish between these two with sufficient care); and in order to show that it is only a mode [of the moving body] and not a substance, just as shape is a mode of the thing shaped, and rest, of the thing which is at rest.**

**... I have also added that the transference is effected *from the vicinity of those bodies contiguous to it into the vicinity of others*, and not from one place to another.** [II, 28]

runt quàm priùs, nec ideò ad centra uſque ſe extenderunt, ſed ab iis æqualiter omni ex parte recedentes, loca ibi ſphærica reliquerunt, à materiâ primi elementi, ex omnibus circumjacentibus locis eò affluente, replenda.

LV. *Quid ſit lux.*

Ea enim eſt lex naturæ[a], ut corpora omnia quæ in orbem aguntur, quantum in ſe eſt, à centris ſui motûs recedant. Atque hîc illam vim, quâ ſic globuli ſecundi elementi, nec non etiam materia primi circa centra S, F, congregata, recedere conantur ab iſtis centris, quàm potero accuratiſſimè explicabo. In eâ enim ſolâ lucem conſiſtere infrà oſtendetur[b]; & ab ipſius cognitione multa alia dependent.

LVI. *Quis conatus ad motum in rebus inanimatis ſit intelligendus.*

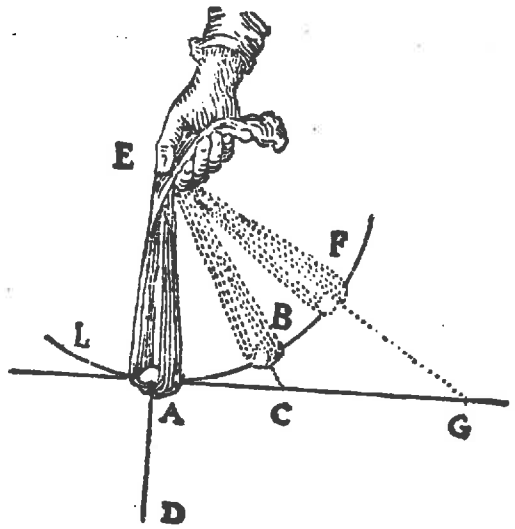
Cùm dico globulos ſecundi elementi recedere conari à centris circa quæ vertuntur, non putandum eſt idcirco me illis aliquam cogitationem affingere, ex quâ procedat iſte conatus; ſed tantùm ipſos ita eſſe ſitos, & ad motum incitatos, ut revera ſint eò verſùs ituri, ſi à nullâ aliâ cauſâ impediantur.

LVII. *Quomodo in eodem corpore conatus ad diverſos motus ſimul eſſe poſſint.*

Quia verò frequenter multæ cauſæ diverſæ agunt ſimul in idem corpus, atque unæ aliarum effectus impediunt, prout ad has vel illas reſpicimus, dicere poſſumus | ipſum eodem tempore tendere, ſive ire conari, verſùs diverſas partes. Ut, exempli cauſâ, lapis A, in fundâ EA, circa centrum E rotatus, tendit quidem ab A verſùs B, ſi omnes cauſæ, quæ occurrunt ad ejus motum determinandum, ſimul ſpectentur, quia revera eò verſùs fertur. Sed ſi reſpiciamus ad ſolam vim motûs quæ in ipſo eſt, dicemus illum, cùm eſt in

a. Pars II, art. XXXIX, p. 63.
b. Pars IV, art. XXVIII.

puncto A, tendere verſùs C, juxta legem motûs ſuprà expoſitam : ponentes ſcilicet lineam AC eſſe rectam, quæ tangit circulum in puncto A[a]. Si enim lapis è fundâ egrederetur, eo temporis momento, quo veniendo ex L pervenit ad punctum A, revera pergeret ab A verſùs C, non verſùs B ; ac quamvis funda hunc



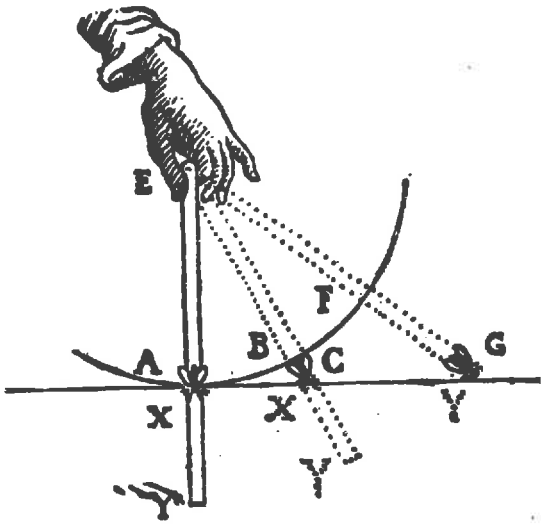

effectum impediat, non tamen impedit conatum. Si denique non reſpiciamus ad totam iſtam vim motûs, ſed tantùm ad illam | ejus partem quæ à fundâ impeditur, eam ſcilicet diſtinguentes ab aliâ ejus parte quæ ſortitur ſuum effectum, dicemus hunc lapidem, dum eſt in puncto A, tendere tantùm verſùs D, ſive recedere conari à centro E ſecundùm lineam rectam EAD.

LVIII. *Quomodo ea quæ circulariter moventur, conentur recedere à centro ſui motûs.*

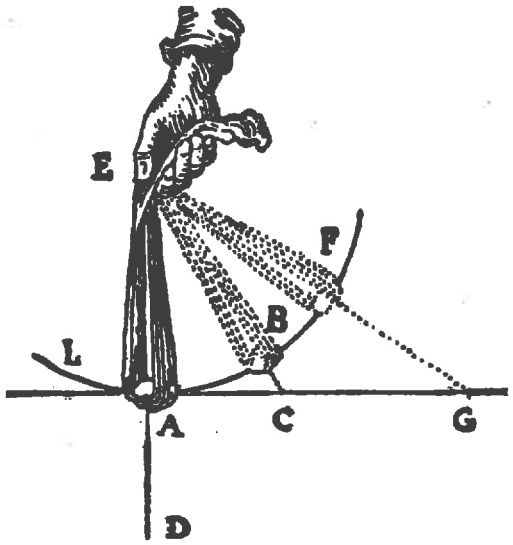
Quod ut clarè intelligatur, conferamus motum quo lapis, in puncto A exiſtens, ferretur verſus C, ſi à nullâ aliâ vi impediretur, cum motu quo formica, in eodem

a. Pars II, art. XXXIX, p. 63.

puncto A exiſtens, moveretur etiam verſus C, ſi linea EY eſſet baculus, ſupra quem rectà incederet ab A




verſus Y, dum interim ipſe baculus verteretur circa centrum E, ac ejuſdem baculi punctum A deſcriberet

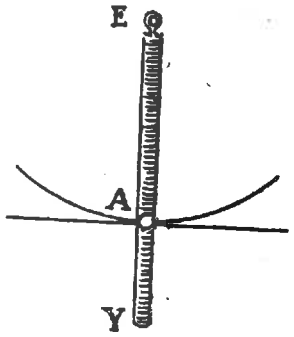



circulum ABF, eſſentque hi duo motus ita inter ſe contemperati, ut formica perveniret ad X cùm bacu-

lus eſſet in C, & ad Y cùm baculus eſſet in G, atque ita ipſa ſemper exiſteret in lineâ rectâ ACG. Ac deinde conferamus etiam eam vim, quâ | idem lapis, actus in fundâ ſecundùm lineam circularem ABF, recedere conatur à centro E, ſecundùm lineas rectas AD, BC, FG, cum conatu qui remaneret in formicâ, ſi vinculo vel glutino aliquo detineretur in puncto A ſupra baculum EY, dum interim iſte baculus eam deferret circa centrum E per lineam circularem ABF; ac ipſa totis viribus conaretur ire verſùs Y, atque ita recedere à centro E ſecundùm lineas rectas EAY, EBY, & ſimiles.

LIX. *Quanta ſit vis iſtius conatûs.*

Scio quidem motum iſtius formicæ fore initio tardiſſimum, atque ideò ejus conatum, ſi tantùm ad principium | motûs referatur, non videri magnum eſſe poſſe: atqui profectò non planè nullus eſt, & dum ſortitur effectum, augetur, adèo ut motus ex eo proveniens ſatis celer eſſe poſſit. Nam, ut adhuc alio utamur exemplo, ſi EY ſit canalis, in quo globulus A contineatur, primo quidem temporis momento, quo iſte canalis agetur in gyrum circa centrum E, globulus A motu tantùm tardiſſimo progredietur verſus Y; ſed ſecundo momento paulò celeriùs incedet: priorem enim vim retinebit, ac præterea novam acquiret à novo conatu recedendi à centro E: quia, quandiu durat motus circularis, tamdiu ille conatus durat, & quaſi renovatur ſingulis momentis. Atque hoc experientia confirmat: ſi enim



canalis EY valde celeriter agatur circa centrum E, brevi globulus, in eo exiſtens, ab A ad Y perveniet. Idemque etiam experimur in fundâ : quò celeriùs enim lapis in eâ rotatur, eò magis funis intenditur ; atque iſta tenſio, à ſolâ vi quâ lapis recedere conatur à centro ſui motûs exorta, exhibet nobis iſtius vis quantitatem.

LX.
*Hunc conatum reperiri in materiâ cœlorum.*

Quod verò hîc de lapide in fundâ, vel de globulo in canali circa centrum E rotato, dictum eſt, facilè intelligitur eodem modo de omnibus globulis ſecundi elementi : quòd nempe unuſquiſque ſatis magnâ vi recedere conetur à centro vorticis in quo gyratur : retinetur enim hinc inde ab aliis globulis circumpoſitis, non aliter quàm lapis à fundâ. Sed præterea iſta vis in illis multùm augetur, ex | eo quòd ſuperiores ab inferioribus, & omnes ſimul à materiâ primi elementi, in centro cujuſque vorticis congregatâ, premantur. Ac primò quidem, ut accuratè omnia diſtinguantur, de ſolis iſtis globulis hîc agemus ; nec ad materiam primi elementi magis attendemus, quàm ſi ſpatia omnia, quæ ab illâ occupantur, vacua eſſent, hoc eſt, quàm ſi plena eſſent materiâ, quæ aliorum corporum motus nullo modo juvaret, nec impediret. Nullam enim aliam eſſe poſſe ſpatii vacui veram ideam, ex antedictis[a] eſt manifeſtum.

LXI.
*Ipſum efficere, ut corpora Solis & Fixarum ſint rotunda.*

Cùm globuli omnes qui volvuntur circa S, in vortice AEI, conentur recedere ab S, ut jam demonſtratum eſt[b], ſatis patet illos, qui ſunt in lineâ rectâ SA, premere ſe mutuò omnes verſùs A ; & illos, qui ſunt

a. Pars II, art. XVII, p. 49.
b. Art. LIV ci-avant, p. 107-108.

Plate VIII

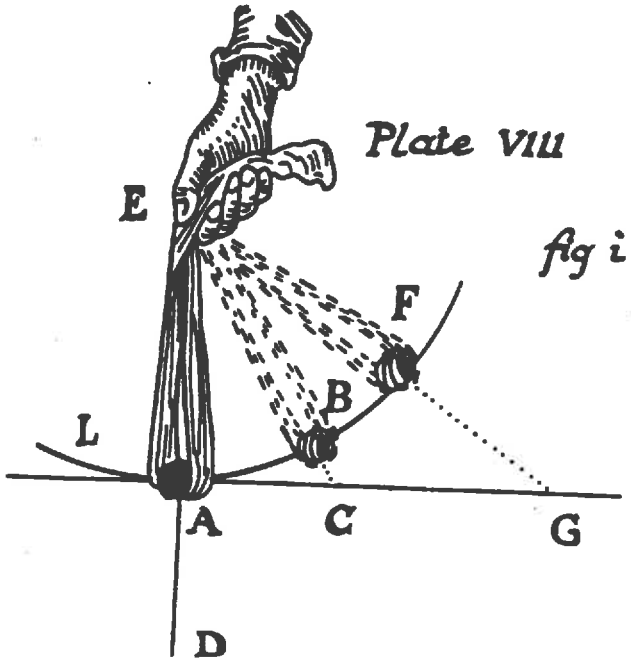



fig i

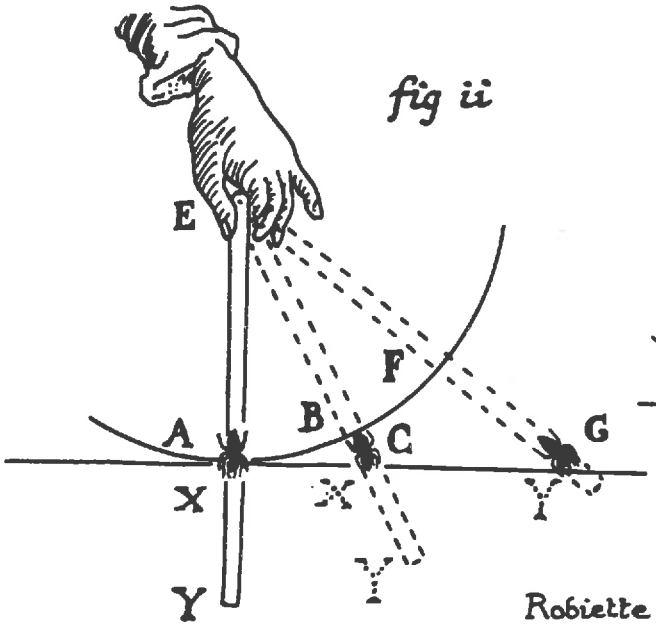



fig ii

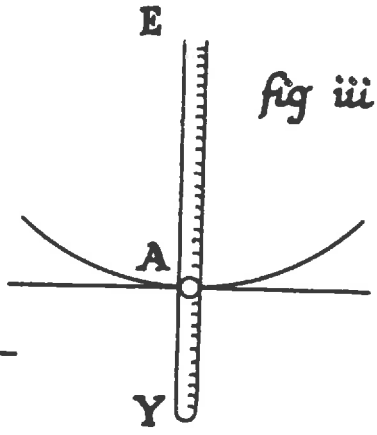



fig iii

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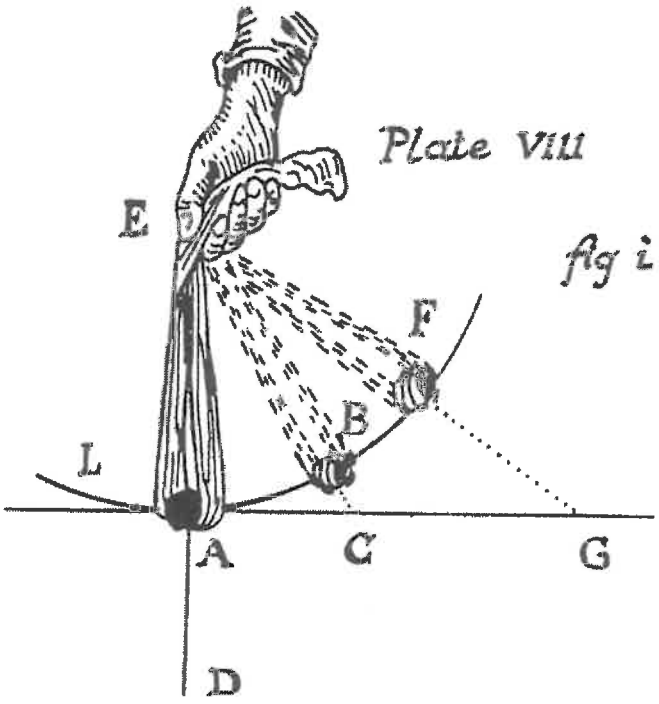


## *How great the force of this striving is*

"We see, too, that the stone which is in a sling makes the rope more taut as the speed at which it is rotated increases; and, since what makes the rope taut is nothing other than the force by which the stone strives to recede from the center of its movement, we can judge the quantity of this force by the tension."

Descartes, *Principia*, III, 59

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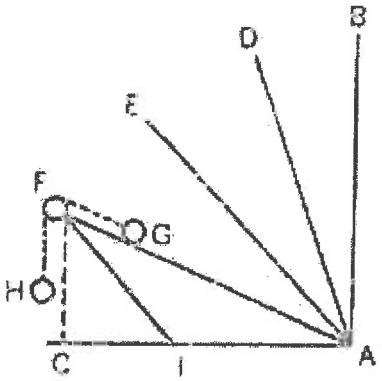
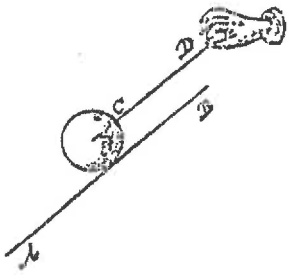
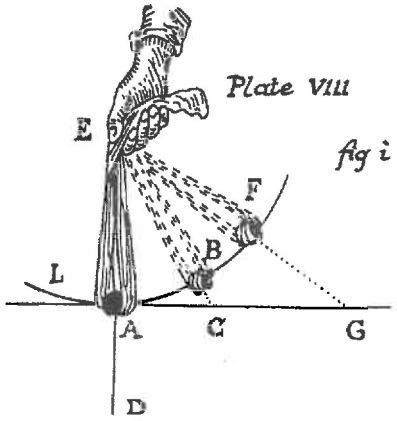
"And we experience the same thing with the sling: by means of the greater speed, to be sure, at which the stone in it rotates, the rope is stretched all the more; and indeed this tension, given rise to by the force alone by which the stone endeavors to recede from the center of its motion, displays to us the quantity of force of this kind."

# Tension in a String as a Measure of an Endeavor toward Motion



## III,34. That the movements of the heavens are not perfectly circular.

**Finally, we must not think that all centers of the Planets are always situated exactly on the same plane, or that the circles they describe are absolutely perfect; let us instead judge that, as we see occurring in all other natural things, they are only approximately so, *and also that they are continuously changed by the passing of the ages.* [emphasis added]**

## III,36. Concerning their longitudinal movement

**… But a few centuries from now, all these things will be observed to have changed {from the way in which they now are}, and {those who will be living at that time will be able to observe that} the individual Planets, and also the Earth, will intersect the plane on which the Ecliptic now is at different places…**

## III,157. The final and most general cause of all the inequalities observed in the movements of bodies in the universe.

**Finally, we shall not wonder that all the Planets slightly deviate in every way, both longitudinally and latitudinally, from those perfect circular motions which they are always attempting. For, inasmuch as all the bodies in the universe are contiguous and act on one another, {there being no possibility of a void}, the movement of each is affected by the movements of all the others and therefore varies in innumerable ways.**

# Two Views of Astronomy

1. **To develop a mathematical account of the motions of celestial bodies that yields calculated (geocentric) longitudes and latitudes that at all times, into the indefinite past and future, agree with observation to within the limits of precision of the observations, invoking considerations from physics where helpful, but with the hope that ultimately the details of the motions will shed light on the underlying physics.**

***The standard: no residual discrepancies***

2. **To develop an account of the physics of the celestial realm – a cosmology, as it were – fully anticipating that this physics will imply that the actual celestial motions are inordinately complicated in ways making any detailed regularities that happen to be discerned in these motions nothing more than transitory happenstance occurrences – i.e. epochal coincidences – and hence of limited significance.**

***The standard: comprehensive unified physics***

# Astrophysical Questions

1. **What is the physics of stars, why do they give off light, and what gives rise to new stars?**

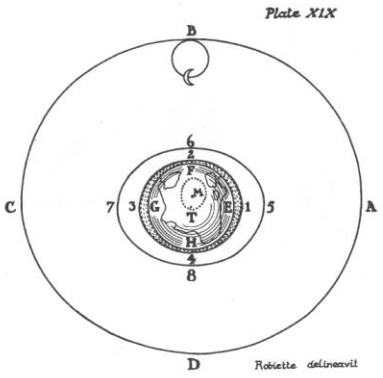
2. **What are sunspots, how do they form, propagate, and evolve?**

3. **What are comets, where do they come from, and where do they go?**

4. **What are planets, how do they form, and why do they persist in orbit?**

5. **What is the general structure of the universe and how does our Sun and its system relate to other nearby stars and their systems?**

6. **What is light, how does it propagate from a source, and what can it tell us about that source?**




**49. Concerning the ebb and flow of the ocean**

**I have already explained, in the Meteorology, the causes of the winds, by which the ocean is agitated in various irregular ways. But there remains another regular movement of the ocean, by which, twice a day in each place, it is raised up and driven down, and meanwhile always flows from the East toward the West. In order to explain the cause of this movement, let us visualize that small vortex of the heaven which has the earth at its center, and which is carried along in a larger vortex around the sun with the earth and the moon. Let ABCD be that small vortex; EFGH, the earth; 1234, the surface of the ocean, which, for the sake of greater clarity, we are supposing completely covers the earth; and 5678, the surface of the air encompassing the earth. Now, if there were no moon in this vortex, point T, which is the center of the earth, would be at point M, which is the center of the vortex; but when the moon is situated near B, this center T must be between M and D. Since the heavenly matter of this vortex is moved somewhat more rapidly than the moon or the earth, which it carries along with it, if point T were not somewhat more distant from B than D, the presence of the moon would impede this heavenly matter from being able to flow as freely between B and T as between T and D. And since the location of the earth in this vortex is determined only by the equality of forces of the heavenly matter flowing around it, it is evident that the earth must therefore approach D to some extent. And in the same way, when the moon is at C, the center of the earth will have to be between M and A; and thus the earth will always recede slightly from the moon. Further, in this way, not only is the space through which the heavenly matter flows between B and T made narrower by the moon at B, but so is the space through which the heavenly matter flows between T and D. It follows that this heavenly matter flows more rapidly in those spaces and therefore presses down more upon the surface of the air at 6 and 8, and upon the surface of the water at 2 and 4, than it would if the moon were not on diameter BD of the vortex. And since the bodies of air and water are fluid and easily obey this pressure, those bodies must be less deep above parts F and H of the earth than if the moon were not on diameter BD; and, on the contrary, they must be deeper at G and E, so that the surfaces of the water 1,3 and of the air 5,7 swell there.**

**50. Why water ascends in 6 1/5 hours, and descends in 6 1/5 hours.**

**51. Why the ocean's tides are greater when the moon is full or new.**

## IV, 201. That imperceptible particles of bodies exist.

**I also consider, in individual bodies, many particles which are not perceived by sense: which may not be approved by those who take their senses as the measure of the things we can know. Yet, if only he considers what is added each hour to those bodies which are gradually being increased, or what is removed from those which are being decreased; who can doubt that there are many bodies so tiny that we do not perceive them by our senses?... Nor do I think that anyone who is using his reason will be prepared to deny that it is far better to judge of things which occur in tiny bodies (which escape our senses solely because of their smallness) on the model of those which our senses perceive occurring in large bodies, than it is to devise I know not what new things, having no similarity with those things that are observed, in order to give an account (*explicanda*) of those things.**

## IV, 203. How we know the figures and movements of imperceptible particles.

**But I attribute determined figures, and sizes, and movements to the imperceptible particles of bodies, as if I had seen them. … Some readers may perhaps ask how I therefore know what they are like. To which I reply: that I first generally considered, from the simplest and best known principles (the knowledge of which is imparted by nature), what the principal differences in the sizes, figure, and situations of bodies which are imperceptible solely on account of their smallness could be, and what perceptible effects would follow from their various encounters. And next, when I noticed some similar effects in perceptible things, I judged that these things had been created by similar encounters of such imperceptible bodies; *especially when it seemed that no other way of explaining these things could be devised.* … Natural effects almost always depend on some devices so minute that they escape our senses. And there are absolutely no judgments in Mechanics which do not also pertain to Physics, of which Mechanics is a part or type…. Accordingly, just as when those who are accustomed to considering automata know the use of some machine and see some of its parts, they easily conjecture from this how the other parts which they do not see are made: so from the perceptible effects and parts of natural bodies, I have attempted to investigate the nature of their causes and of their imperceptible parts.** [emphasis added]

## IV, 204. That it suffices if I have explained what imperceptible things may be like, even if perhaps they are not so.

**And although perhaps in this way it may be understood (*intelligatur*) how all natural things could have been created, it should not therefore be concluded that they were in fact so created…. And indeed I most willingly concede this to be true, and will think that I have achieved enough if those things which I have written are only such that they correspond accurately to all phenomena of nature. And indeed this will also suffice for the needs of everyday life, because Medicine and Mechanics, and all other arts which can be perfected with the help of Physics, have as their goal only those effects which are perceptible and which accordingly ought to be numbered among the phenomena of nature.**

## IV, 205. That those things which I have explained [*explicui*] here do seem at least morally certain, however

**However, lest some injury to truth may occur here, it must be considered that there are things which are held to be morally certain, that is, to a degree which suffices for the needs of everyday life; although, if compared to the absolute power of God, they are uncertain. Thus, for example, if someone wishes to read a message written [i.e. encyrpted] in Latin letters, to which their true meaning has not been given and if, upon conjecturing [a key to the cypher] … he finds by this means certain Latin words are formed by these letters: he will not doubt that the true meaning of that message is contained in these words, even if he knows this solely by conjecture, and even though it may perhaps be the case that the person who wrote the message did not [follow that key, but some other] …, and thus concealed a different meaning in the message. It would however be so difficult for this to happen, {especially if the message contains many words}, that it does not seem credible. But those who notice how many things concerning the magnet, fire, and the fabric of the entire World have been deduced here from so few principles (even though they may suppose these principles only by chance and without reason), will perhaps still know that it could scarcely have occurred that so many things should be consistent with one another, if they were false.**

## IV, 206. That on the contrary they seem more than morally certain.

**Besides, there are, even among natural things, some which we judge to be absolutely and more than morally certain; basing our judgment on the Metaphysical foundation that God is supremely good and by no means deceitful, and that, accordingly, the faculty which He gave us to distinguish the true from the false cannot err when we use it correctly and perceive something clearly with its help. Such are Mathematical demonstrations; such is the knowledge that material things exist; and such are all evident demonstrations which are made concerning material things. These reasonings of ours will perhaps be included among the number of these absolutely certain things by those who consider how they have been deduced in a continuous series from the first and simplest principles of human knowledge. Especially if they sufficiently understand that we can feel no external objects unless some local movement is excited by them in our nerves; and that such movement cannot be excited by the fixed stars, very distant from here, unless some movement also occurs in these and in the whole intermediate heaven: for once these things have been accepted, it will scarcely seem possible for all the rest, at least the more general things which I have written about the World and the Earth, to be understood otherwise than as I have explained [*explicata*] them.**

**From Chambers Murray Latin-English Dictionary, 1933**

***explano, explanare.*** ***to make completely level;***

a. ***to set forth clearly;***

b. ***to expound, make clear, explain;***

***c. to pronounce*** or ***utter clearly.***

***explico, explicare.*** ***to unfold, unroll, unfurl;***

1. ***to extend, display;***

2.a. ***to unravel*** a complicated or difficult matter, ***to disentangle, set in order, settle, adjust;***

b. By words: ***to develop, unfold, set forth in detail,*** and so, ***to make clear and intelligible;***

c. ***to disentangle, set free.***

# An Alternative, More Empirical

# Foundation for Cartesian Physics

*All departures of any body from rest or from uniform motion in a straight line require an external action or force arising from some other body (in contact with it) that effects a change in the motion of the body in question by transferring some of its motion to it, with the aggregate of their total motion remaining the same after as it was before.*

# Descartes' Contributions to Mechanics

- **Global conservation principles as a constraint**
- **Curvilinear motion requires external action**
- **Measuring the magnitude of that action**
- **Force as a determiner of (quantity of) motion**
- **Impact and recoil as a fundamental process**
- **Relevance of fluid motion, esp. vortex motion**
- **The demand for universal first principles**

# Questions Highlighted

1. **What, if any, quantity is invariably conserved during every change in motion?**

2. **What is the magnitude of the external action required for curvilinear motion and with what does it vary?**

3. **Can mathematically precise rules be given for impact and recoil that agree with everyday observation?**

4. **What is the proper measure of quantity of motion, and with what does it vary?**

5. **What are the fundamental principles of mechanics – i.e. the principles that must be met in the solution of every problem in mechanics?**

6. **What is the magnitude of the "force" (*vis*) of bodies to resist changes in motion, and with what does it vary?**

7. **What is the relationship between the weight of a body, its specific gravity, and the quantity of matter forming it?**

8. **How can we determine, once and for all, whether vacuums – spaces free of all matter – are possible?**

9. **What is the physics of vortex motion, and do vortices have gradients in speed and pressure that Descartes says?**

# Aims of Empirical Research

1. **To provide an account of the world around us that gives us a better understanding of it, at least to a reasonable degree of detail.**

2. **To marshal empirical considerations toward establishing secure answers to those questions that (at the time) lend themselves to such answers.**

3. **To provide means for improving our daily practical lives, especially through enabling us to achieve ends we otherwise could not achieve.**

# 1651: Marking a Century of Breakthroughs

1. **The full recognition that *apparent* celestial motions are consistent with incompatible alternatives about what is moving in orbit about what.**

   **Copernicus, Tycho, Kepler**

2. **The importance given to discrepancies in calculated versus observed (geocentric) longitudes and latitudes in astronomy.**

   **Tycho, Kepler, Horrocks**

3. **The shift from compounding curvilinear motions out of circular motions to compounding them out of rectilinear motions.**

   **Descartes, Galileo, Gassendi**

4. **The increased emphasis on designing and developing experiments that address comparatively specific questions.**

   **Mersenne, Galileo, Riccioli**

5. **A marked relaxation of the strictures of classical mathematics, opening the way to a wide range of new mathematical methods for solving problems**

   **Viète, Descsartes. Fermat**

6. **The stress on "efficient causation" over its Aristotelian alternatives in answers to why- and how-questions about changes that occur in nature.**

   **Bacon, Mersenne, Descartes**

***Increasing respect for the idea that the empirical world ought, somehow or other, to be the ultimate arbiter of all questions about it.***