DISCOVERIES AND OPINIONS
OF GALILEO

Including
The Starry Messenger (1610)
Letter to the Grand Duchess Christina (1615)
And Excerpts from
Letters on Sunspots (1613)
The Assayer (1623)

Translated
with an Introduction and Notes
by Stillman Drake

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Meanwhile from Rome and elsewhere there came insistent requests to know whether I had anything to say on this subject, from friends and patrons who perhaps did not know that I was ill. I replied to them that I had only some questions to raise, which I was unable to write down because of my infirmity, but that I hoped these ideas of mine would soon be included in a discourse by a friend who had taken the trouble to collect them. That is all I said, and it has been told in several places by Guiducci. There was no need for Sarsi to pass him off as a mere copyist. But since Sarsi wants it so, let it be; meanwhile let Guiducci accept my defense of his treatise in return for the honor he did me.

I have never claimed (as Sarsi pretends) that my opinion was certain to be swiftly carried by the winds to Rome. That usually happens only with the words of great and celebrated men, which really far exceeds the bounds of my ambition. It is true, though, that in reading Sarsi’s book I have wondered that what I said never did reach Sarsi’s ears. Is it not astonishing that so many things have been reported to him which I never said, nor even thought, while not a single syllable reached him of other things that I have said over and over again? But perhaps the winds that blow the clouds and those chimeras and monsters that tumultuously take shape in them had not the strength to carry solid and weighty things.

In Sarsi I seem to discern the firm belief that in philosophizing one must support oneself upon the opinion of some celebrated author, as if our minds ought to remain completely sterile and barren unless wedded to the reasoning of some other person. Possibly he thinks that philosophy is a book of fiction by some writer, like the Iliad or Orlando Furioso, productions in which the least important thing is whether what is written there is true. Well, Sarsi, that is not how matters stand. Philosophy is written in this grand book, the universe, which stands continually open to our
gaze. But the book cannot be understood unless one first learns to comprehend the language and read the letters in which it is composed. It is written in the language of mathematics, and its characters are triangles, circles, and other geometric figures without which it is humanly impossible to understand a single word of it; without these, one wanders about in a dark labyrinth.

Sarsi seems to think that our intellect should be enslaved to that of some other man. . . . But even on that assumption, I do not see why he selects Tycho. . . . Tycho could not extricate himself from his own explanation of diversity in the apparent motion of his comet; but now Sarsi expects my mind to be satisfied and set at rest by a little poetic flower that is not followed by any fruit at all. It is this that Guiducci rejected when he quite rightly said that nature takes no delight in poetry. That is a very true statement, even though Sarsi appears to disbelieve it and acts as if acquainted with neither nature nor poetry. He seems not to know that fables and fictions are in a way essential to poetry, which could not exist without them, while any sort of falsehood is so abhorrent to nature that it is as absent there as darkness is in light.

Guiducci wrote that “people who wish to determine the location of a comet by means of parallax must first establish that the comet is a fixed and real object and not a mere appearance, since reasoning by parallax is indeed conclusive for real things but not for apparent ones.” . . . Sarsi says that no author worth considering, ancient or modern, has ever supposed a comet to be a mere appearance; hence that his teacher, who was disputing only with such men and did not aspire to victory over any others, did not need to remove comets from the company of mere images. To this I reply in the first place that for the same reason Sarsi might let Guiducci and me alone, as we are outside the circle of those worthy ancient and modern authors against whom his teacher was contending. We meant only to address those men, ancient or modern, who try in all their studies to investigate some truth in nature. We meant to steer clear of those who ostentatiously engage in noisy contests merely to be popularly judged victors over others and pompously praised. . . . Guiducci, in the hope of doing something that would be welcome to men studious of truth, proposed with all modesty that henceforth it would be good to consider the nature of a comet, and whether it might be a mere appearance rather than a real object. He did not criticize Father Grassi or anyone else who had not previously done this. Now Sarsi rises up in arms and passionately strives to prove that this suggestion is beside the point and false to boot. Yet in order to be prepared for anything (lest the idea appear worthy of some consideration), he robs me of any possible credit by calling this “an ancient notion of Cardan⁶ and Telesio,” which his teacher disparages as a fantasy of feeble philosophers who had no followers. And under this pretense, without the least shame for his disrespect, he robs those men of their reputations in order to cover up a slight oversight of his teacher’s. . . . But I must not neglect to show, for his benefit and in their defense, how implausible is his deduction that their science was poor from their having had few followers.

Perhaps Sarsi believes that all the host of good philosophers may be enclosed within four walls. I believe that they fly, and that they fly alone, like eagles, and not in flocks like starlings. It is true that because eagles are rare birds they are little seen and less heard, while birds that fly like starlings fill the sky with shrieks and cries, and wherever they settle befoul the earth beneath them. Yet if true philosophers are like eagles they are not [unique] like the phoenix. The crowd of fools who know nothing, Sarsi, is infinite. Those who know very little of philosophy are numerous. Few indeed are they who really know some part of it, and only One knows all.

To put aside hints and speak plainly, and dealing with science as a method of demonstration and reasoning capa-

⁶ Jerome Cardan (1501–76) was a noted mathematician and the author of works on philosophy, medicine, astronomy, and nearly every other branch of learning.
Nature), moving around (as it never has), sweeps along with it the element of fire (which is not proved to exist) and along with this the exhalations which in turn kindle the material of comets—a material whose location we cannot establish with certainty, and which we are positive is not combustible. Sarsi here puts me in mind of the saying of a very witty poet:

> By Orlando's sword, which they have not  
   And perhaps which they never shall have  
   These blows of blind men have been given... 

Sarsi next wants to make Guiducci agree with Aristotle, and to show that they have both stated the same conclusion when one of them says that motion is the cause of heat, and the other says that the cause is not motion but the brisk rubbing of two hard bodies. And since it is Guiducci's statement that is correct, Sarsi interprets the other one by saying that if indeed motion, as motion, is not the cause of heat, nevertheless friction is not created without motion, so that at least derivatively we may say that motion is the cause. But if that is what Aristotle meant, why didn't he say "friction"? When a man can say definitely what he means by using a simple and appropriate word, why employ an inappropriate one that requires qualification and ultimately becomes transformed into something quite different? But assuming that this was Aristotle’s meaning, it still differs from Guiducci’s; for to Aristotle any rubbing of bodies would suffice, even of tenacious ones or of the air itself, whereas Guiducci requires two solid bodies, for he considers that trying to pulverize the air is as great a waste of time as grinding water in the proverbial mortar.

It is my opinion that the original proposition may be quite true, taken in the simplest sense of the words it contains, and that perhaps it came from some good philosophical school of antiquity, but that Aristotle failed to fathom the minds of the ancients who propounded it, and deduced his false conception accordingly. Nor would this be the only proposition that is inherently true but is understood by the Peripatetics in a false sense. Of this I shall say more some other time...

Really, I do not believe that Guiducci would say (as Sarsi pretends) that in order to become hot, bodies must first be rarefied, and that rarefaction diminishes them, and that the thinner parts fly away... In the process under discussion one must consider on the one hand the body that is to produce the heat, and on the other hand the body which is to receive heat. Sarsi thinks Guiducci would require the excitation and the consumption of parts to take place in the body receiving the heat, whereas I believe the body that is diminished would be the one that generates heat...

When Sarsi heated his bit of copper by pounding it many times, I can well believe that he detected no diminution in its weight even by the most delicate balance. But I do not think on that account that none can have taken place; it may have been too minute to be perceptible in any balance whatever. Let me ask Sarsi whether he thinks any difference of weight could be detected in a silver button before and after it is gilded. He must say no, as we see gold reduced to such thin leaf that it will sustain itself upon the quiet air and drop with extreme slowness; and with such gold any metal may be gilded. Now this button may be used two or three months before the gilding will wear off, and yet since the gilt is ultimately consumed it must be diminishing every day and every hour.

Or take a ball of musk and carry it with you for a fortnight; it will fill with odor a thousand rooms and streets, which cannot happen without some diminution of material; yet you will find none by weighing it. Thus Sarsi may see that insensible reductions of weight do occur from consumption over a period of months on end, let alone the few minutes he may have persisted in hammering away at his bit of copper. And precisely by this difference we may measure the sensitivity of the assayer's balance in compar-

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16 Boiardo, Orlando Innamorato iii, c. vi, 50, 3–5.
ison with that of the philosopher's steelyard. And note that the tenuous material which produces heat is even more subtle than that which causes odor, for the latter cannot leak through a glass container, whereas the material of heat makes its way through any substance.

Here Sarsi objects, saying, "If testing with the balance is insufficient to reveal so small a consumption, how will you have it shown?" The objection is ingenious, though not so profound as to be incapable of solution by a little physical logic. Here are the steps of the argument. Of bodies that are rubbed together, some are certainly not consumed, others are quite perceptibly consumed, and still others are indeed consumed, but insensibly. Our senses show us that those which are not consumed at all by rubbing, such as two polished mirrors, are not heated by rubbing, either. We know that those are heated which are perceptibly consumed, as iron when it is being filed. Therefore when we are in doubt whether things are consumed by rubbing we may believe that they are if they are sensibly heated, while those which are not heated may be said not to be consumed.

Before going on I wish to add something for Sarsi's instruction. To say, "This body has not lost weight in the balance, and hence no part of it has been consumed," is fallacious reasoning. It is possible for part of something to be consumed and yet for it to gain weight instead of losing it. This will happen when the specific gravity of that which is consumed is less than that of the medium in which it is being weighed. For instance a very knotty piece of wood taken from near the root may sink when placed in water. Under water let it weigh four ounces. Now cut away some of the lighter parts and leave the knotty portions; the former, being of less specific gravity than the water, gave some support to the entire mass. Hence I say it may happen that the parts left will weigh more in water than the entire piece of wood did. Now it may be that in filing or rubbing together pieces of iron, sticks, or stones, some particles of material less dense than air become separated from them; if nothing else is removed, this would leave the body heavier than before. What I say is not entirely improbable, or merely a refuge which will leave the adversary some trouble in refuting it. For if you carefully observe what happens in breaking glass or stones, you will see some perceptible fumes emerge and rise high in the air, which must be lighter than air. I first noticed this when breaking the corners off a piece of glass and rounding it with a key or some other piece of iron. Besides the little pieces of various sizes which flew off and fell to the ground, I saw a subtle smoke always arising. And apart from what we see, what we smell is a clear sign that some Sulfurous or Bituminous parts may be ascending which remain invisible but make themselves known by their odor.

Let Sarsi see from this how superficial his philosophizing is, except in appearance. But let him not think he can reply with additional limitations, distinctions, logical technicalities, philosophical jargon, and other idle words, for I assure him that in sustaining one error he will commit a hundred others that are more serious, and produce always greater follies in his camp. . . . Why must I attribute lightning to vehement motion when I see that fire is not excited without the rubbing of solid bodies which do not exist among the clouds? And heat lightning occurs when no commotion is perceived in the air or in clouds. This theory of his, I think, is no more inherently true than the statements of these same philosophers when they attribute the rumbling of thunder to the tearing apart of clouds, or to their knocking together. Actually in the brilliance of the brightest flashes of lightning not the slightest movement or change of shape is discerned in the clouds, and this is just when thunder is being formed. I pass over in silence the fact that these philosophers say that no noise is produced by the striking of wool or hemp, and require the percussion of solid bodies to make sound; and then again when it suits their purposes they assert that mists and clouds striking together will render the loudest of all sounds. Tractable and benign indeed is such philosophy, so pleasantly and readily adapting itself to men's needs and wishes!

Now let us go on to examine the arrows in flight and the
lead balls hurled by catapults which are supposed to be set afire and melted in the air, according to the authority of Aristotle, many famous poets, other philosophers, and historians. But it is wrong to say, as Sarsi does, that Guiducci and I would laugh and joke at the experiences adduced by Aristotle. We merely do not believe that a cold arrow shot from a bow can take fire in the air; rather, we think that if an arrow were shot when afire, it would cool down more quickly than it would if it were held still. This is not derision; it is simply the statement of our opinion.

Sarsi goes on to say that since this experience of Aristotle's has failed to convince us, many other great men also have written things of the same sort. To this I reply that if in order to refute Aristotle's statement we are obliged to represent that no other man has believed it, then nobody on earth can ever refute it, since nothing can make those who have believed it not believe it. But it is news to me that any man would actually put the testimony of writers ahead of what experience shows him. To adduce more witnesses serves no purpose, Sarsi, for we have never denied that such things have been written and believed. We did say they are false, but so far as authority is concerned yours alone is as effective as an army's in rendering the events true or false. You take your stand on the authority of many poets against our experiments. I reply that if those poets could be present at our experiments they would change their views, and without disgrace they could say they had been writing hyperbolically—or even admit they had been wrong.

Well, if we cannot have the presence of your poets (who, as I say, would yield to experience), we do have at hand archers and catapultists, and you may see for yourself whether citing your authorities to them can strengthen their arms to such an extent that the arrows they shoot and the lead balls they hurl will take fire and melt in the air. In that way you will be able to find out just how much force human authority has upon the facts of Nature, which remains deaf and inexorable to our wishes. You say there is no longer an Acestes or a Mezentius or other mighty paladin? I shall be content to have you shoot an arrow not with a simple longbow, but with the stoutest steel crossbow, or use a catapult drawn by levers and windlasses that could not be managed by thirty of your ancient heroes. Shoot ten arrows, or a hundred; and if it ever happens that on one of them the feathers so much as slightly tan—let alone its shaft taking fire or its steel tip melting—I shall not only concede the argument but forfeit your respect, which I regard so highly. . . .

I cannot but be astonished that Sarsi should persist in trying to prove by means of witnesses something that I may see for myself at any time by means of experiment. Witnesses are examined in doubtful matters which are past and transient, not in those which are actual and present. A judge must seek by means of witnesses to determine whether Peter injured John last night, but not whether John was injured, since the judge can see that for himself. But even in conclusions which can be known only by reasoning, I say that the testimony of many has little more value than that of few, since the number of people who reason well in complicated matters is much smaller than that of those who reason badly. If reasoning were like hauling I should agree that several reasoners would be worth more than one, just as several horses can haul more sacks of grain than one can. But reasoning is like racing and not like hauling, and a single Arabian steed can outrun a hundred plowhorses. So when Sarsi brings in this multitude of authors it appears to me that instead of strengthening his conclusion he merely ennobles our case by showing that we have outreasoned many men of great reputation.

17 Two powerful warriors of Virgil's Aeneid: "Acestes . . . discharged his shaft . . . ; the arrow, flying among the watery clouds, took fire and with flames marked out its path, till being quite consumed it vanished." (v, 525 ff.) "Mezentius himself, having laid aside his arms, thrice whirling about his head the thong, discharged a hissing sling, and with the half-melted lead clove asunder the temples of the son of Arces." (ix, 585 ff.)
If Sarsi wants me to believe with Suidas\(^\text{18}\) that the Babylonians cooked their eggs by whirling them in slings, I shall do so; but I must say that the cause of this effect was very different from what he suggests. To discover the true cause I reason as follows: “If we do not achieve an effect which others formerly achieved, then it must be that in our operations we lack something that produced their success. And if there is just one single thing we lack, then that alone can be the true cause. Now we do not lack eggs, nor slings, nor sturdy fellows to whirl them; yet our eggs do not cook, but merely cool down faster if they happen to be hot. And since nothing is lacking to us except being Babylonians, being Babylonians is the cause of the hardening of eggs, and not friction of the air.” And this is what I wished to discover. Is it possible that Sarsi has never observed the coolness produced on his face by the continual change of air when he is riding post? If he has, then how can he prefer to believe things related by other men as having happened two thousand years ago in Babylon rather than present events which he himself experiences? . . .

Sarsi says he does not wish to be numbered among those who afford the sages by disbelief and contradicting them. I say I do not wish to be counted as an ignoramus and an ingrate toward Nature and toward God; for it they have given me my senses and my reason, why should I defer such great gifts to the errors of some man? Why should I believe blindly and stupidly what I wish to believe, and subject the freedom of my intellect to someone else who is just as liable to error as I am? . . .

Finally Sarsi is reduced to saying with Aristotle that if the air ever happened to be abundantly filled with warm exhalations in the presence of various other requisites, then leaden balls would melt in the air when shot from muskets or thrown by slings. This must have been the state of the air when the Babylonians were cooking their eggs, . . . and at such times things must go very pleasantly for people who are being shot at. But, Sarsi says, since to find such conditions is a matter of chance, and one that does not occur too frequently, we must not resort to experiments for settling such questions. So, Sarsi, if experiments are performed thousands of times at all seasons and in every place without once producing the effects mentioned by your philosophers, poets, and historians, this will mean nothing and we must believe their words rather than our own eyes? But what if I find for you a state of the air that has all the conditions you say are required, and still the egg is not cooked nor the lead ball destroyed? Alas! I should be wasting my efforts, . . . for all too prudently you have secured your position by saying that “there is needed for this effect violent motion, a great quantity of exhalations, a highly attenuated material, and whatever else conduces to it.” This “whatever else” is what beats me, and gives you a blessed harbor, a sanctuary completely secure.

What I had in mind, though, was to suspend our argument and wait quietly until some new comet came along. I imagined that while this lasted you and Aristotle would grant me that since the air was then properly disposed for kindling the comet, it would likewise be suitable for melting lead balls and cooking eggs, inasmuch as you seem to require the same condition for both effects. It was then that I would have had us set to work with our slings, eggs, bows, muskets, and cannons so that we might clear up this matter for ourselves. And even without waiting for a comet we might find an opportune time when in midsummer the air flashes with heat lightning, as you assign all these “burnings” to a single cause. But I suppose that when you failed to behold a melting of lead balls or even the cooking of eggs under such conditions you would still fail to give in; you would say that this “whatever else conduces to the effect” was lacking. If you would only tell me what this “whatever else” is, I should endeavor to provide it. But if not I shall have to abandon my little scheme, though I do believe it would turn out against you . . .

It now remains for me to tell Your Excellency, as I promised, some thoughts of mine about the proposition “motion is the cause of heat,” and to show in what sense this may

\(^{18}\) Suidas was a Greek lexicographer of the tenth century.
be true. But first I must consider what it is that we call heat, as I suspect that people in general have a concept of this which is very remote from the truth. For they believe that heat is a real phenomenon, or property, or quality, which actually resides in the material by which we feel ourselves warmed.\textsuperscript{19} Now I say that whenever I conceive any material or corporeal substance, I immediately feel the need to think of it as bounded, and as having this or that shape; as being large or small in relation to other things, and in some specific place at any given time; as being in motion or at rest; as touching or not touching some other body; and as being one in number, or few, or many. From these conditions I cannot separate such a substance by any stretch of my imagination. But that it must be white or red, bitter or sweet, noisy or silent, and of sweet or foul odor, my mind does not feel compelled to bring in as necessary accompaniments. Without the senses as our guides, reason or imagination guarded would probably never arrive at qualities like these. Hence I think that tastes, odors, colors, and so on are no more than mere names so far as the object in which we place them is concerned, and that they reside only in the consciousness. Hence if the living creature were removed, all these qualities would be wiped away and annihilated. But since we have imposed upon them special names, distinct from those of the other and real qualities mentioned previously, we wish to believe that they really exist as actually different from those.

\textsuperscript{19} The ensuing passages are generally considered to entitle Galileo to credit for anticipating the fundamental concepts of the empiricist philosophy developed chiefly by John Locke at the close of the seventeenth century. The basic tenets are of course much older, belonging to the atomism of Democritus (b. 460 B.C.), a doctrine which was particularly repugnant to Aristotle. While this exposition is of no little philosophical and scientific interest (inasmuch as empiricism, rightly or wrongly, has been closely associated with the development of modern science), Galileo was no philosophical empiricist. He attached no less importance to reason than to experiment, and he had no doubt about the independent truth of mathematical propositions, the denial of which has always involved empiricist philosophers in serious difficulty with the best logicians.
that there are bodies which constantly dissolve into minute particles, some of which are heavier than air and descend, while others are lighter and rise up. The former may strike upon a certain part of our bodies that is much more sensitive than the skin, which does not feel the invasion of such subtle matter. This is the upper surface of the tongue; here the tiny particles are received, and mixing with and penetrating its moisture, they give rise to tastes, which are sweet or unsavory according to the various shapes, numbers, and speeds of the particles. And those minute particles which rise up may enter by our nostrils and strike upon some small protuberances which are the instrument of smelling; here likewise their touch and passage is received to our like or dislike according as they have this or that shape, are fast or slow, and are numerous or few. The tongue and nasal passages are providently arranged for these things, as the one extends from below to receive descending particles, and the other is adapted to those which ascend. Perhaps the excitation of tastes may be given a certain analogy to fluids, which descend through air, and odors to fires, which ascend.

Then there remains the air itself, an element available for sounds, which come to us indifferentely from below, above, and all sides—for we reside in the air and its movements displace it equally in all directions. The location of the ear is most fittingly accommodated to all positions in space. Sounds are made and heard by us when the air—without any special property of “sonority” or “transsonority”—is ruffled by a rapid tremor into very minute waves and moves certain cartilages of a tympanum in our ear. External means capable of thus ruffling the air are very numerous, but for the most part they may be reduced to the trembling of some body which pushes the air and disturbs it. Waves are propagated very rapidly in this way, and high tones are produced by frequent waves and low tones by sparse ones.

To excite in us tastes, odors, and sounds I believe that nothing is required in external bodies except shapes, numbers, and slow or rapid movements. I think that if ears, tongues, and noses were removed, shapes and numbers and motions would remain, but not odors or tastes or sounds. The latter, I believe, are nothing more than names when separated from living beings, just as tickling and titillation are nothing but names in the absence of such things as noses and armpits. And as these four senses are related to the four elements, so I believe that vision, the sense eminent above all others in the proportion of the finite to the infinite, the temporal to the instantaneous, the quantitative to the indivisible, the illuminated to the obscure—that vision, I say, is related to light itself. But of this sensation and the things pertaining to it I pretend to understand but little; and since even a long time would not suffice to explain that trifle, or even to hint at an explanation, I pass this over in silence.

Having shown that many sensations which are supposed to be qualities residing in external objects have no real existence save in us, and outside ourselves are mere names, I now say that I am inclined to believe heat to be of this character. Those materials which produce heat in us and make us feel warmth, which are known by the general name of “fire,” would then be a multitude of minute particles having certain shapes and moving with certain velocities. Meeting with our bodies, they penetrate by means of their extreme subtlety, and their touch as felt by us when they pass through our substance is the sensation we call “heat.” This is pleasant or unpleasant according to the greater or smaller speed of these particles as they go pricking and penetrating; pleasant when this assists our necessary transpiration, and obnoxious when it causes too great a separation and dissolution of our substance. The operation of fire by means of its particles is merely that in moving it penetrates all bodies, causing their speedy or slow dissolution in proportion to the number and velocity of the fire-corpuscles and the density or tenuity of the bodies. Many materials are such that in their decomposition the greater part of them passes over into additional tiny corpuscles, and this dissolution continues so long as these continue to meet with further matter capable of being so resolved. I do not
believe that in addition to shape, number, motion, penetration, and touch there is any other quality in fire corresponding to "heat"; this belongs so intimately to us that when the live body is taken away, heat becomes no more than a simple name. . . .

Since the presence of fire-corpuses alone does not suffice to excite heat, but their motion is needed also, it seems to me that one may very reasonably say that motion is the cause of heat. . . . But I hold it to be silly to accept that proposition in the ordinary way, as if a stone or piece of iron or a stick must heat up when moved. The rubbing together and friction of two hard bodies, either by resolving their parts into very subtle flying particles or by opening an exit for the tiny fire-corpuses within, ultimately sets these in motion; and when they meet our bodies and penetrate them, our conscious mind feels those pleasant or unpleasant sensations which we have named heat, burning, and scalding. And perhaps when such attrition stops at or is confined to the smallest quanta, their motion is temporal and their action calorific only; but when their ultimate and highest resolution into truly indivisible atoms is arrived at, light is created.20 This may have an instantaneous motion, or rather an instantaneous expansion and diffusion,21 rendering it capable of occupying immense spaces by its—I know not whether to say its subtlety, its rarity, its immateriality, or some other property which differs from all these and is nameless.

This lucky guess should entitle Galileo to consideration as having anticipated many modern scientific discoveries—in the same sense as that in which medieval philosophers anticipated Galileo in the discovery of the principle of inertia. At present it is customary to praise their happy conjectures and to overlook his. But perhaps that is because they made so many unsupported guesses, and he so few.

The erroneous view that light is transmitted instantaneously was later withdrawn by Galileo, and in the Discourses of 1698 he even proposed an experiment for determining the speed of light. It was, of course, too crude to succeed. Yet Galileo's discoveries played a part in its successful measurement, for this was eventually accomplished by means of observations of eclipses of the satellites of Jupiter.

Finally I cannot resist speaking about Sarsi's amazement at my hopeless ineptitude in the employment of experiments, inasmuch as he himself errs as badly as a man can in that same activity. You, Sarsi, must show us that an interposed flame would not suffice to hide the stars. In order to convince us by experiments, you say that if we look through flames at people, firebrands, coals, printed pages, and candles, we shall see all these quite plainly. Did it never enter your head to tell us to try looking at stars? Why did you not say to us at the outset, "Interpose a flame between the eye and some star, and the star will be made neither more nor less visible"? Surely there is no lack of stars in the sky. Now is this to be a skillful and prudent experimentalist?

I ask you whether the comet's flame is like our flames, or whether it has a different nature. If its nature is different, experiments made with our flames are not conclusive. If it is like our flames, then you might have made us look at stars through our flames and left out firebrands, candlesnuffs, and such things. Instead of saying that print may be read through a candle flame, you might have said that a star may be so perceived. . . . You are obliged to kindle a very distant flame as large as a comet and to make us see stars through it. . . . But in order to put you at your ease and give you every advantage, I shall be content with much less. Instead of placing the fire as far away as a comet, I am satisfied with a distance of one hundred yards. In place of the thickness of a comet, merely ten yards will suffice. And since you say the object to be seen gains an advantage from being bright, let it be one of the stars which