THE SOURCES OF SCIENCE

Number 5

THE SOURCES OF SCIENCE

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Kepler's Conversation with Galileo's Sidereal Messenger

Kepler's Conversation with Galileo's Sidereal Messenger

First Complete Translation,
With an Introduction and Notes,
by

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PREFACE

THE PUBLICATION OF this book fulfills at long last the intention I expressed in "The Naming of the Telescope" (New York, 1947). But shortly after that volume appeared, various events combined to divert my attention to numerous other projects in the history of science. However, the invitation recently extended to me by the Department of the History and Philosophy of Science at Indiana University to conduct a graduate seminar on Kepler's Contributions to Astronomy and Physics permitted me to resume my long interrupted work on Kepler's "Conversation," just as a research grant from the National Science Foundation had previously enabled me to continue my analysis of a closely related treatise by Kepler. In finally presenting his "Conversation" to the modern reader, I am deeply grieved that by the inexorable edict of the ultimate arbiter of human destiny, the completed work cannot be seen by Henry Schuman, lover of good books, to whose memory this volume is affectionately dedicated.

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INTRODUCTION

THE HISTORY OF observational astronomy may be divided into three periods: naked-eye, telescopic, and radio. The transition from the first to the second period occurred in 1610. In mid-March of that year the first book to report astronomical observations made with a telescope was published in Venice by Galileo Galilei (1564–1642). The four hundredth anniversary of the birth of this outstanding Italian scientist is now being commemorated all over the world with appropriate ceremonies. His brief book, the "Sidereal Message" (or "Message," as we shall call it for the sake of brevity) electrified contemporary scientists and thinkers. Not only did it describe phenomena whose very existence had previously been only imagined or debated, but its newly discovered facts raised questions of profound philosophical importance. Everywhere perplexed people looked to the acknowledged experts for guidance in this intellectually disturbing situation.

One such expert was Johannes Kepler (1571–1630), Imperial Mathematician to Rudolph II, emperor of the Holy Roman Empire. This emperor was personally interested in astronomy, and himself had made telescopic observations of the moonspots as early as January, 1610. The first copy of Galileo's "Message" to reach Prague, then the capital of the Holy Roman Empire, belonged to the emperor. He showed it to Kepler, and wanted to hear what the Imperial Mathematician thought about it.

Another person who was intensely interested in learning how Kepler was affected by the "Message" was Galileo himself. For this purpose he sent a copy of his book to the Tuscan ambassador at Prague. Together with this copy Galileo transmitted a request for Kepler's reaction in written form; this request was to be passed on by the ambassador to Kepler.

The ambassador had this copy of Galileo's "Message" delivered to Kepler on April 8, 1610. The same emissary conveyed an invitation to the Imperial Mathematician to visit the ambassador on April 13th. When Kepler kept this appointment, the ambassador read Galileo's request to him. The official couriers were scheduled to return to Tuscany in less than a week, and Kepler promised to have his response to Galileo's "Message" ready before they departed. Kepler's "letter of April 19," as we shall designate it, was put in the ambassador's hands on that day. It was purposely left unsealed so that the ambassador could read it if he so desired. But he was too busy on that particular day to do so, and therefore he dispatched it to Galileo unread.

Many other people were eager to know Kepler's opinion about Galileo's "Message." Instead of replying to each one individually, the Imperial Mathematician decided to have his letter of April 19 printed at his own expense. Thereupon various friends raised various objections to the letter. In his usual manner Kepler answered these objections in a prefatory "Notice to the Reader." Then, on May 3, 1610, he dedicated the little work to the ambassador, and it was published in Prague.

In selecting a title for this book Kepler committed a lamentable error. The key word in Galileo's title was "nuncius" or "nuntius," which we have translated as "Message." But this same Latin word could also mean "messenger." Had Kepler not acted in such a hurry, he might have noticed Galileo's characterization of the "nuncius" as containing observations.[1] Then Kepler might have reflected that whereas a message could contain observations, a messenger could not. This apparently unimportant distinction was completely overlooked by Kepler in his haste. Taking the word in its more familiar sense, he entitled his book "Conversation with the Sidereal Messenger." He thereby unintentionally supplied a powerful weapon to the deadliest enemies of Galileo, whom he would never have deliberately injured in the slightest way. But an adversary of Galileo delightedly seized the weapon unwittingly forged by the Imperial Mathematician, and publicly ridiculed that impudent scoundrel Galileo for having dared to pass himself off as a messenger from heaven.[2]

Not only did Kepler's title incorporate this calamitous misunderstanding of Galileo's title, but it itself was in turn misunderstood. In Kepler's poorly chosen title the opening words were "Dissertatio cum nuncio sidereo," which he undoubtedly intended to be taken as meaning "Conversation with the Sidereal Messenger." However, as he rushed the book headlong into print, he took no precautions to make clear in what sense he was using the term "dissertatio." This Latin word, like its English derivative "dissertation," could signify a written essay. It was in fact so interpreted by a distinguished editor of Galileo's works, who evidently did not have a copy of Kepler's "Dissertatio" before him. Making an inference based exclusively on its title, he described the "Dissertatio" as a composition which was published at Prague in 1610 together with ("cum") a reprint or second edition of Galileo's "Sidereus nuncius."[3] As a result of this confusion, a wholly imaginary Prague 1610 edition of Galileo's "Message" began to infest the bibliography of the subject. A further consequence was that Kepler's "Dissertatio" came to be viewed as an introduction[4] or addition[5] to the nonexistent Prague reprint of Galileo's "Message."

However, as we have already seen, Kepler's "Conversation" was neither an introduction nor an addition to Galileo's "Message." In reality it was Kepler's immediate response to Galileo's "Message." In compliance with Galileo's express invitation, Kepler wrote the "Conversation" between April 13 and April 19, 1610. Thus, for a week or less, there was an unusual intellectual encounter between two geniuses. Such a dialogue is rare indeed in the annals of science, which can show few, if any, parallels to this colloquy between two of the greatest astronomers of all time.

This colloquy may serve to teach us something about the advancement of science. Kepler and Galileo pursued very different paths in their search for the truth about the physical universe. If their procedures were quite different, so were their personalities. Galileo was more the practical man, handy with tools, and not much given to far-reaching speculation. Kepler was less earthbound, his daring imagination often soaring high above the realm of known or suspected fact into the attenuated atmosphere of sheer theory or even unrestrained fantasy. The mansion of science has many rooms, which were not constructed by any one method, nor by any one kind of builder.

Kepler's letter of April 19, as we saw above, was written in less than a week. During the next two weeks he made a number of alterations in the private letter of April 19, and thereby changed it into the published "Conversation." Wherever these deletions and expansions are not perfunctory, but actually reveal a further development in Kepler's thinking, their significance is pointed out in the Notes.

The original letter of April 19 is preserved in the National Central Library of Florence, Italy, and was published with the correspondence of Galileo.[6] The Florence manuscript was produced by an amanuensis. His scribal errors were corrected by Kepler, who also added some expressions between the lines and in the margins.

The printed "Conversation" has been republished by three scholars: in the only complete edition of Kepler's works;[7] in the national edition of Galileo;[8] and in the splendid edition of Kepler's collected works which is still in progress.[9]

An unscholarly, indeed an unethical, reprint of the "Conversation" was issued at Florence in 1610. When Kepler learned of this piracy, he wrote to Galileo on October 25, 1610: "I hear that my 'Conversation' has been reprinted at Florence; I should like to see a copy of it."[10] Then in December, 1610, Kepler drafted a letter to Galileo which he did not actually send off. In its place he dispatched another letter on January 9, 1611, which was mainly concerned with Galileo's most recent telescopic discoveries. These exciting developments crowded out of the abortive letter of December, 1610, the following passage:

> I published my "Conversation" at my own expense, and I sent the proper number to Frankfurt [for the book fair]. Therefore the Florentine publisher inflicted damages on me by his edition. This in itself is cruel; whether it is also illegal, is up to Florence. For if it does not recognize the authority of the emperor, I have no ground for complaint; but if it does, the book was protected by a license. Because of this uncertainty it will not be clear how I am to be obligated to His Excellency the Ambassador. However, if I am not mistaken, he resides at Prague in the service, not of the publisher, but of the Grand Duke [of Tuscany], and he claims to be generous in his own right. Yet if I won a lawsuit against the publisher, I would sentence him to the following punishment. He should pay for your work on a good wide convex lens, which would be a part of a sphere twelve feet in radius or its equivalent. For here at Prague I could readily find someone to make a concave lens for me. The difficulty is only in the convex lenses. For with their own equipment they

> accomplish little, and they pretend to despise my instructions. This, I understand, is their way of eliciting advice. I don't have the money to build a machine at home, and besides I am not handy, being given to speculation only.[11]

The pirated Florence, 1610 edition of the "Conversation," about which Kepler complained with justice but to no effect, contained a reprint of Kepler's Latin text. It did not contain an "Italian translation," despite Arthur Koestler.[12] In fact, to this very day there is still no Italian translation of Kepler's "Conversation." Nor is there a complete translation into any other language. To be sure, a German translator claimed that he had made a complete translation.[13] But his claim must be rejected, since he omitted both the Dedication and the Notice to the Reader. What is presented here, then, is the first complete translation of Kepler's "Conversation."[14]

From the very beginning the attitude of Kepler's "Conversation" toward Galileo's "Message" was grossly misrepresented. For example, Georg Fugger, a member of the wealthy banking family, wrote to Kepler from Venice on May 28, 1610: "I have carefully read your elegant essay on[15] Galileo's 'Message.' If he is so disposed, he will readily recognize that his mask has been torn away from him."[16] The metaphor of the mask here replaced a different simile used by Fugger in an earlier letter to Kepler. Writing also from Venice on April 16, 1610, Fugger had said more explicitly about Galileo: "That man knows how to gather up others' feathers here and there and, like the crow in Aesop, he is in the habit of adorning himself with them. Thus he wants to be regarded as the inventor of the ingenious telescope, although a certain Dutchman, who traveled through France to this place, first brought it here."[17] Actually, of course, Galileo did not pretend that he had invented the telescope.[18] Hence there was no mask to be ripped away from his face by Kepler, nor were there any false feathers to be plucked. On the contrary, with the ample generosity which Kepler characteristically displayed in welcoming the scientific achievements of others, in the "Conversation" Kepler wholeheartedly acclaimed the immense contributions to astronomy that were made by Galileo's "Message."

A facsimile of the Prague 1610 edition of Kepler's "Conversation" was recently issued by Poerschke & Weiner of Munich. In conjunction therewith, Werner Lehmann of Gräfelfing, near Munich, published a new German translation of the "Conversation," by Dr. Franz Hammer, who omitted the Dedication and the Postscript as unessential for his purpose. Both the facsimile Latin text and Dr. Hammer's German version were presented to the International Symposium on the History of Astronomy at the Twelfth General Assembly of the International Astronomical Union at Hamburg in 1964. Dr. Hammer's rendering and its brief appendix reached me when the present volume was going to press.

JOHANNES KEPLER

Imperial Mathematician

Conversation with the Sidereal Messenger

Recently Sent to Mankind

by

Galileo Galilei

Mathematician of Padua

ALCINOUS

"Free in mind must be he who desires to have understanding."[19]

Licensed by the Emperor and printed at

PRAGUE

BY DANIEL SEDESANUS[20]

1610

To His Most Illustrious and Most Reverend Lordship,

Lord GIULIANO de' MEDICI,[21]

AMBASSADOR OF THE MOST SERENE GRAND DUKE OF TUSCANY TO HIS SACRED IMPERIAL MAJESTY,

my Most Worshipful Lordship.

Most Illustrious Lord, I wrote this letter to Galileo Galilei, professor of mathematics at the renowned University of Padua,[22] with reference to his "Sidereal Messenger," and it has now been set up in type. I find no more appropriate person to whom to dedicate it than your Most Illustrious Lordship. For it was at your instance that it was composed. In the first place, you sent[23] me a copy of the "Sidereal Messenger" on April 8th by the hand of Thomas Seget,[24] and you made an appointment for me to meet you on April 13th. Then, when I appeared, you read me Galileo's request in his communication to you,[25] and you added your own exhortation. Upon hearing these words, I promised to prepare something in time for the scheduled departure of the couriers, and I kept my pledge. But even though you had had access to my letter, quite recently you earnestly asked me to give you a copy, if I had kept any, so that you could read it. For, having been busy on that day,[26] you had not been able to examine the original, although I had delivered it unsealed. Again I agreed to comply as soon as I had made it public. When I first drafted it, and again when I sent it to the printer,[27] I was particularly delighted that Galileo, to whom it was addressed, was in the employ of the Medici[28]; that the ambassador of Prince Medici, Grand Duke of Tuscany,[29] himself a Medici by birth, sought this service from me; and lastly that the nature of the subject matter, with which I had to deal, was such (since the truth was to be made known) that to honor the name of the Medici would come within the author's purview.

Therefore, Most Illustrious Lord, accept a document which was once private and the property of Galileo, which became public through being printed, and which by a public dedication has now become yours. From this dedication learn my love for proclaiming the truth, and also the glory, which rests on truth alone, of the Medicean rule; in this latter activity the writings of Galileo take precedence. Regard me as disposed most eagerly to obey your Most Illustrious Lordship. Finally, count me among your servants. Farewell. May 3, 1610.[30]

Your Most Illustrious Lordship's
faithful and obedient servant,

JOHANNES KEPLER

HIS SACRED IMPERIAL MAJESTY'S MATHEMATICIAN.

NOTICE TO THE READER[31]

WHEN MANY PEOPLE asked my opinion about Galileo's "Sidereal Messenger," I decided to satisfy them all by adopting the short cut of circulating in printed form the letter which I sent to Galileo (and which was drafted in great haste, amidst unavoidable obligations, to meet a deadline).[32]

But after it was printed, my friends cautioned me that it seemed a little too unconventional in conception. One of them wanted the introduction done away with; another would have liked to soften certain expressions which, to short-sighted eyes, might appear to impute to my opponent[33] views at variance with scholastic tradition; some[34] also desired less extensive praise of Galileo, in order to make room for the verdict of famous men, whose attitude, they hear, differs from mine.[35]

Therefore I resolved to advise the reader that everybody has his own preference. Whereas most debaters get all heated up, I regard humor as a more pleasant tone in discussions. Other authors strive for impressiveness in the exposition of philosophy by the weightiness of their assertions; yet they often prove amusing, unintentionally. I seem by nature cut out to lighten the hard work and difficulty of a subject by mental relaxation, conveyed by the style.

With regard to the introduction, then, the reader will bear in mind that it was intended for those who presumably were familiar with the dedication of my recently published "Commentary on Mars,"[36] which they see mentioned there. For the military analogy, which I jokingly used in that public book,[37] has been continued, with no less propriety, in this introduction to a private letter.[38]

To the second objection my reply is the same. As an intellectual diversion, I conjure up a contest between rivals, clashes, the triumph of the winner, horrible threats, the punishment of the loser, disgrace, chains, prison, exile.[39] These struggles betoken a serious outcome, as though each contestant were battling for his own opinion as he would for altar and hearth. But people in the academic world need not be reminded (let others at least imagine) what it means *to defend one's position*. When a debater does so, he adopts as his own not only true and traditional views but also absurdities and falsities (in the schools frequently, godless, baneful, and blasphemous beliefs as well). He professes, according to the exigencies of his speech, either that he favors these ideas, or accepts them, upholds them, proves them, or will prove them. Yet at heart he believes nothing less, his motive being merely to give his opponent practice in defending the truth. Hence a disputation becomes more entertaining if an unsophisticated speaker is debarred from the truth as his position by being unexpectedly assigned a contrary thesis, and by being ordered to defend what he never thought would have to be defended.

So far as the third item of criticism is concerned, surely I have not colored my remarks about Galileo. I have always followed the practice of praising what I deemed well said by others, and of refuting what was badly said. I have never belittled or laid false claim to the ideas of others, when I had none of my own. I have never fawned on others, nor have I been self-effacing if I made some better or prior discovery by my own exertions.

I do not think that Galileo, an Italian, has treated me, a German, so well that in return I must flatter him, with injury to the truth or to my deepest convictions.

Yet let no one assume that by my readiness to agree with Galileo I propose to deprive others of their right to disagree with him. I have praised him, but all men are free to make up their own minds. What is more, I have undertaken herein to defend some of my own views also. I have done so with a conviction of their truth and with serious purpose. Yet I swear to reject them without reservation, as soon as any better informed person points out an error to me by a sound method.

To the Noble and Most Excellent Signor

GALILEO GALILEI,

GENTLEMAN OF FLORENCE,
PROFESSOR OF MATHEMATICS AT THE UNIVERSITY OF PADUA,

JOHANNES KEPLER,

HIS SACRED IMPERIAL MAJESTY'S MATHEMATICIAN,

sends his most cordial greetings.

I

For a long time I had stayed at home to rest, thinking of nothing but you, most distinguished Galileo, and your letters. For at the latest book fair there had been released to the public[40] my treatise entitled "Commentary on the Motions of Mars," a labor of many years. From that time on, like a general who had won glory enough through a most strenuous military campaign, I took some respite from my studies. I supposed that among others Galileo too, the most highly qualified of all, would discuss with me by mail the new kind of astronomy or celestial physics which I had published,[41] and that he would resume our interrupted correspondence, which had begun twelve years before.[42]

But behold, a surprise report about my Galileo is brought to Germany by the couriers around March 15th. Instead of reading a book by someone else, he has busied himself with a highly startling revelation[43] (to say nothing about the other subjects in his little book) of four previously unknown planets, discovered by the use of the telescope with two lenses. Johann Matthäus Wackher of Wackenfels, the illustrious Councilor of His Sacred Imperial Majesty and Referendary of the Sacred Imperial Aulic Council,[44] told me the story from his carriage in front of my house. Intense astonishment seized me as I weighed this very strange pronouncement. Our emotions were strongly aroused (because a small difference of opinion of long standing between us had unexpectedly been settled). He was so overcome with joy by the news, I with shame, both of us with laughter, that he scarcely managed to talk, and I to listen.[45] My amazement grew when Wackher stated that men of the highest reputation, raised by their erudition, seriousness, and steadfastness far above the unreliability of ordinary people, were transmitting these messages about Galileo, while his book was still at the printer's and would be made available by the next couriers.

When I left Wackher's presence, I was influenced most by Galileo's prestige, achieved by the soundness of his judgment and the subtlety of his mind. Therefore I bethought myself how there could be any increase in the number of planets[46] without harm to my "Cosmographic Mystery," which I published thirteen years before.[47] In that book Euclid's five solids,[48] to which Proclus, following Pythagoras and Plato, applies the term "cosmic,"[49] permit no more than six planets around the sun.[50]

Yet it is apparent from the preface to that book that I too at that time was looking for additional planets around the sun,[51] but in vain.[52]

Then, as I pondered over this development, the following idea occurred to me and I promptly[53] conveyed it to Wackher. The earth, which is one of the planets (according to Copernicus[54]), has its own moon revolving around it as a special case. In the same way, Galileo has quite possibly seen four other very tiny moons running in very narrow orbits around the small bodies of Saturn, Jupiter, Mars, and Venus. But Mercury, the last of the planets around the sun, is so deeply immersed in the sun's rays that Galileo has not yet been able to discern anything similar there.

Wackher, on the other hand, maintained that these new planets undoubtedly circulate around some of the fixed stars[55] (he had for a considerable time been making some such suggestion to me on the basis of the speculations of the Cardinal of Cusa[56] and of Giordano Bruno[57]). If four planets have hitherto been concealed up there, what stops us from believing that countless others will be hereafter discovered in the same region, now that this start has been made? Therefore, either this world is itself infinite,[58] as Melissus thought[59] and also the Englishman William Gilbert, the founder of the science of magnetism[60]; or, as Democritus[61] and Leucippus[62] taught, and among the moderns, Bruno[63] and Bruce,[64] who is your friend, Galileo,[65] as well as mine,[66] there is an infinite number of other worlds[67] (or earths, as Bruno puts it[68]) similar to ours.[69]

Such was my opinion, such was his,[70] while, our hopes aroused, we waited[71] for Galileo's book with an extraordinary longing to read it.

I succeeded in seeing the first[72] copy, by permission of the Emperor,[73] and in leafing through it rapidly. I behold "great and most marvelous sights proposed to philosophers and astronomers,"[74] including myself,[75] if I am not mistaken; I behold "all lovers of true philosophy summoned to the commencement of great observations."[76]

At once I craved to plunge into the subject, inasmuch as I was invited; and since I had written on the same topic six years before,[77] I yearned to discuss with you, most accomplished Galileo, in a highly agreeable kind of discourse, the many undisclosed treasures of Jehovah the creator, which He[78] reveals to us one after another. For who is permitted to remain silent at the news of such momentous developments? Who is not filled with a surging love of God, pouring itself copiously forth through tongue and pen?[79]

My eagerness was stimulated by the orders of the Most August Emperor Rudolph, who requested my opinion about this subject. But what shall I say about Wackher? I went to see him without the book, avowing that I had read it. There was bad feeling[80] and even a quarrel. In the end we both agreed[81] that I was not to delay becoming as expert as possible in this field.

While I was thinking the matter over, your letter to the ambassador of the Most Illustrious Grand Duke of Tuscany[82] arrived, full of affection for me. You did me the honor of thinking that so great a man in particular should encourage me to write; and you sent along a copy of the book[83] and added your own admonition. With the utmost graciousness the ambassador fulfilled this function as a kindness to you, and he most generously placed me under his patronage.

By my own inclination, then, at the instance of my friends, and at your urgent request I shall undertake this task. I am moved by some hope that if you should deem this letter of mine worthy of display,[84] it may bring you this advantage: against the obstinate critics of innovation, for whom anything unfamiliar is unbelievable, for whom anything outside the traditional boundaries of Aristotelian narrowmindedness is wicked and abominable, you may advance reinforced by one partisan.[85]

II

I may perhaps seem rash in accepting your claims so readily with no support from my own experience. But why should I not believe a most learned mathematician, whose very style attests the soundness of his judgment? He has no intention of practicing deception in a bid for vulgar publicity, nor does he pretend to have seen what he has not seen.[86] Because he loves the truth, he does not hesitate to oppose even the most familiar opinions, and to bear the jeers of the crowd with equanimity. Does[87] he not make his writings public, and could he possibly hide any villainy that might be perpetrated? Shall I disparage him, a gentleman of Florence, for the things he has seen? Shall I with my poor vision[88] disparage him with his keen sight? Shall he with his equipment of optical instruments be disparaged by me, who must use my naked eyes because I lack these aids? Shall I not have confidence in him, when he invites everybody to see the same sights, and what is of supreme importance, even offers his own instrument in order to gain support on the strength of observations?

Or would it be a trifling matter for him to mock the family of the Grand Dukes of Tuscany, and to attach the name of the Medici to figments of his imagination, while he promises real planets?[89]

Why is it that I find part of the book verified by my own experience and also by the affirmations of others? Is there any reason why the author should have thought of misleading the world with regard to only four planets?

Three months ago the Most August Emperor raised various questions with me about the spots on the moon. He was convinced that the images of countries and continents are reflected in the moon as though in a mirror.[90] He asserted in particular that Italy with its two adjacent islands[91] seemed to him to be distinctly outlined. He even offered his glass for the examination of these spots on subsequent days, but this was not done. Thus at that very same time, Galileo, when you cherished the abode of Christ our Lord above the mere appellation[92] [of a Galilean], you vied[93] in your favorite occupation with the ruler of Christendom (actuated by the same restless spirit of inquiry into nature).

But this story of the spots in the moon is also quite ancient. It is supported by the authority of Pythagoras[94] and Plutarch,[95] the eminent philosopher[96] who also, if this detail helps the cause, governed Epirus with the power of a proconsul under the Caesars.[97] I say nothing about Mästlin[98] and my treatise on "Optics," published six years ago; these I shall take up later on in their proper place.[99]

Such assertions about the body of the moon are made by others on the basis of mutually self-supporting evidence. Their conclusions agree with the highly[100] illuminating observations which you report on the same subject. Consequently I have no basis for questioning the rest of your book and the four satellites[101] of Jupiter. I should rather wish that I now had a telescope[102] at hand, with which I might anticipate you in discovering two satellites of Mars (as the relationship seems to me to require) and six or eight[103] satellites of Saturn, with one each perhaps for Venus[104] and Mercury.

For this search, so far as Mars is concerned, the most propitious time will be next October, which will show Mars in opposition to the sun and (except for the year 1608) nearest to the earth, with the error in the predicted position exceeding 3°.[105]

III

Well then, I shall discuss with you, Galileo, things which are absolutely certain and which may be seen, I confidently hope, with my own eyes. I shall follow the plan of your book, but I shall also touch upon all the parts of philosophy which are threatened with destruction or strengthened or clarified by your "Messenger." Hence there will be no residue to worry the reader who is devoted to philosophy, either to deter him from having faith in you, or to induce him to spurn the philosophy which has hitherto prevailed.

IV

The first section of your little book deals with the construction of the telescope. Its magnifying power is so great that the object viewed shows a thousandfold increase in surface. This enlargement is possible if the diameter appears 32 times longer.[106] But if the observer's estimate approximates an impression of the normal size, the object must then seem 32 times nearer. For the eye does not see distance, but infers it, as we learn in optics.[107] Suppose, for example, that a man 3200 paces away is subtended by an angle 32 times greater than that which, without a telescope, subtends a second man 100 paces away. Since the eye regards it as certain that the distant man has the usual height, it will judge that he is no more than 100 paces away. A contributing factor is the sharp definition bestowed on the image by the telescope.

So powerful a telescope seems an incredible undertaking to many persons, yet it is neither impossible nor new. Nor was it recently produced by the Dutch,[108] but many years ago it was announced by Giovanni Battista della Porta in his "Natural Magic,"[109] Book XVII, Chapter 10, "The Effects[110] of a Crystal Lens." And as evidence that not even the combination of a concave with[111] a convex lens is a novelty, let us quote Della Porta's words. Here is what he says:

> When you put your eye behind the middle of the lens, you will see far-away things so near that you seem almost to touch them with your hand. You will recognize your friends at a considerable distance. You will see the writing in a letter, placed at the

> proper range, so big that you may read it clearly. If you turn the lens, so that you look at the letter sideways, you will see the characters enlarged enough to be read even at a distance of 20 paces. *Indeed, if you know how to multiply the lenses, I have no doubt that you will descry the tiniest symbol at 100 paces,* as the characters are magnified by one lens after another.[112] People with bad eyesight should use glasses according to the condition of their vision. Anybody who learns how to fit them correctly will gain no small secret. Concave lenses enable us to see quite clearly objects at a distance; convex lenses, objects close at hand. Hence you will be able to use them to improve your vision. Through a concave lens you see distant objects small but clear; through a convex lens, nearby objects larger but blurred. *If you know how to combine both types correctly,* you will see remote as well as nearby objects larger and clear. To many of my friends, to whom distant objects used to look obscure and nearby objects blurred, I have given no small help, with the result that they saw everything to perfection.

This is what he says in Chapter 10.[113]

Over Chapter 11 he sets a new heading,[114] "Lenses[115] Whereby Anyone Can See to Unimaginable Distances." But his discussion of their construction (which he also explains) is so involved that you do not know what he is talking about, whether he is still dealing[116] with transparent lenses, as in the previous chapter, or introducing an opaque polished mirror. I myself recall one such mirror, which reflects far-away objects on a very large scale without regard to their distance. Hence it shows them close by and also magnified in proportion, as clearly as can be expected from a mirror (which is necessarily dark in color).

Preceding this passage of Della Porta's book I noticed the following complaint at the beginning of Chapter 10:[117]

"Nobody has yet published the theory and properties of concave and convex lenses and glasses,[118] which are so essential to human needs." Six years ago in my "Optical Part of Astronomy"[119] I endeavored to make clear by a lucid geometrical proof what happens in simple lenses.[120]

In my fifth chapter, where I set forth the details of the process of vision, there may be seen on page 202[121] a diagram in which drawings of a concave and convex lens are joined exactly as they are generally combined nowadays in the familiar tubes.[122] Did the reading of Della Porta's "Magic" give rise to this device? Or did some Dutchman, following Della Porta's instructions, manufacture many examples of this instrument as commodities for sale, the obligation to refrain from doing so having ceased with Della Porta's death?[123] Even if not, that diagram on page 202 of my book could itself surely have indicated the construction to an alert reader,[124] especially if he examined my proofs in conjunction with Della Porta's text.

Nor is it beyond belief that expert sculptors of painstaking[125] workmanship, who use glasses to inspect the details of a figure, may also have accidentally stumbled on this device, while uniting convex lenses with concave in various ways, in order to choose the combination most serviceable to the eyes.

I do not advance these suggestions for the purpose of diminishing the glory of the technical inventor, whoever he was. I am aware how great a difference there is between theoretical speculation and visual experience; between Ptolemy's discussion of the antipodes[126] and Columbus' discovery of the New World, and likewise between the widely distributed tubes with two lenses and the apparatus with which you, Galileo, have pierced the heavens. But here I am trying to induce the skeptical[127] to have faith in your instrument.

After I began to work on my "Optics," the Emperor questioned me quite frequently about Della Porta's aforementioned devices. I must confess that I disparaged them[128] most vigorously, and no wonder, for he obviously mixes up the incredible with the probable. And the title of Chapter 11 ("To Extend Vision to Unimaginable Distances") seemed to involve an optical absurdity; as though vision took place by a process of emanation, and lenses sharpened the ejaculations of the eye so that they would travel farther than if no lenses were employed; or if vision takes place by a process of reception, as Della Porta acknowledges, as though in that case lenses[129] supplied or increased the light to make things visible. Rather is it true that no lens can ever detect objects which do not of themselves impart to our eyes some degree of light as the medium through which the objects acquire visibility.

Furthermore, I believed that the air is dense[130] and blue in color,[131] so that the minute parts of visible things at a distance are obscured and distorted. Since this proposition is intrinsically certain, it was vain, I understood, to hope that a lens would remove this substance of the intervening air from visible things. Also with regard to the celestial essence, I surmised some such property as could prevent us, supposing that we enormously magnified the body of the moon to immense proportions, from being able to differentiate its tiny particles in their purity from the lowest celestial matter.[132]

For these reasons, reinforced by other obstacles besides, I refrained from attempting to construct the device.

But now, most accomplished Galileo, you deserve my praise for your tireless energy. Putting aside all misgivings, you turned directly to visual experimentation. And indeed by your discoveries you caused the sun of truth to rise, you routed all the ghosts of perplexity together with their mother, the night, and by your achievement you showed what could be done.

Under your guidance[133] I recognize that the celestial substance is incredibly tenuous.[134] To be sure, this property is made known on page 127 of my "Optics."[135] If the relative densities of air and water[136] are compared with the relative densities of the aether and air,[137] the latter ratio undoubtedly shows a much greater[138] disparity. As a result, not even the tiniest particle of the sphere of the stars (still less of the body of the moon, which is the lowest of the heavenly bodies[139]) escapes our eyes, when they are aided by your instrument. A single fragment of the lens interposes much more matter (or opacity)[140] between the eye and the object viewed than does the entire vast region of the aether. For a slight indistinctness arises from the lens, but from the aether none at all. Hence we must virtually concede, it seems, that that whole immense space is a vacuum.

With eagerness, then, I await your instrument, Galileo. Yet, if fate smiles on me so that I can overcome the obstacles and attempt the mechanical construction, I shall exert myself energetically in that endeavor, pursuing alternative courses. On the one hand, I shall increase the number of lenses.[141] They will have on either side perfectly spherical surfaces of very slight curvature. I shall place them at fixed intervals in the tube, the outer lenses being a little wider.[142] Even so, the eye will be located within the limits of the area where parallel rays[143] passing through all the lenses converge; with regard to these limits, see pages 190 and 440 of my "Optics."[144] On the other hand, to enable me more easily to correct the aberration[145] (should there be any) in a single surface, I shall design a lens shaped like a nipple, to be used by itself. One of its surfaces will be practically plane, because its curvature will amount to only ½°[146] or 30′[147] of a spherically convex shell. The other surface, which is directed toward the eye, will not be spherical. My intention is to avoid what is illustrated by the diagram on page 194,[148] namely, distortion and confusion of the parts of the object under observation, the subject treated in Proposition 18 on page 193.[149] Instead, the second surface will take the shape of a nipple, as shown in the diagram on page 198.[150] Hence it will resemble the crystalline lens of the eye, because it will be bounded by the curvature of a hyperbolic line.[151] This is the figure which I sought in the diagram on page 106[152] for the sake of optical devices,[153] as indicated on pages 96 and 109.[154] The aim is to achieve undistorted vision, in which the images of the parts of the object under observation are enlarged proportionally, as set forth on page 105.[155]

These are the conditions, I say, which I shall observe in setting up the convex lens, for the purpose of magnifying objects in the field of vision. I shall place the eye not far from the spot where the rays from all points of the object under observation converge at a common focus (this is the function of the hyperbolic nipple).[156] The hyperbola will be extended so far that a ray from this point or center will make an angle of 27° with the tangent at the edge of the hyperbola, and will therefore be refracted about 9°. Thus I shall have at either edge a refraction of about 30½°, but proportionally less in between.[157]

Now the rays from a single point[158] of an object shining so far away come down to the nipple[159] practically parallel. Thereafter they converge and enter the crystalline lens of the eye. Being refracted by the crystalline lens, they meet at a point close behind it.[160] Then they diverge again until, spreading out as though from the tip of a pencil, they strike the retina. Thus from every point on the moon light falls on a separate area[161] of the retina, so that the image becomes quite confused. Therefore I shall adapt a concave lens to the individual eye of each observer in accordance with the variations in their vision.[162] In this way the convergence of the rays from any one point will be stopped by a refraction in the opposite direction accomplished by the concave lens. The rays will diverge instead, and will enter the crystalline lens as though they were coming from some nearby point. After being refracted by the crystalline lens, they will find their points of convergence on the retina itself. This is the definition of clear vision. I have proved all this on page 202 of my "Optics."[163]

So much for the instrument. Now so far as its use is concerned, you have certainly discovered an ingenious method of ascertaining to what extent objects are magnified by your instrument,[164] and how individual minutes and fractions of minutes can be discerned in the heavens.[165] Since your achievement along these lines vies with Tycho Brahe's highly precise accuracy of observation, it may not be amiss to digress somewhat.

That master of all the sciences, Johannes Pistorius,[166] asked me more than once,[167] I recall, whether Brahe's observations were so refined that in my opinion absolutely nothing could be lacking in them. I vigorously maintained that the pinnacle had been reached, and that nothing further was left to human enterprise, because the eyes would not permit greater precision, nor would the effect of refraction, which alters the position of the stars with reference to the horizon. In rebuttal, he steadfastly declared that some day somebody would come along who would devise a more exact procedure with the help of lenses.[168] I objected on the ground that their refractive properties made lenses unsuitable for reliable observations. But now at last I see that Pistorius was in part[169] a true prophet. To be sure, Brahe's observations speak for themselves and need no praise. For what an arc of 60°[170] is in the heavens, or 34′,[171] is known through Brahe's instruments by themselves.[172] But whereas Brahe in this way measured celestial degrees in the heavens (or even I determined the diameter of the moon by my optical device[173]), now your telescope, Galileo, surpasses these attainments. Accepting the numerical results recorded by Brahe and me, it subdivides them with the utmost nicety into minutes and fractions of minutes. It couples itself with Brahe's observational method in a most appropriate marriage, so that Brahe has good reason to rejoice at your method of observation, and you must base your method on Brahe's.

Would you like me to express my feelings? I want your instrument for the study of lunar eclipses, in the hope that it may furnish the most extraordinary aid in improving,[174] and where necessary in recasting, the whole of my[175] "Hipparchus" or demonstration of the sizes and distances of the three bodies, sun, moon, and earth.[176] For the variations in the solar and lunar diameters, and the portion of the moon that is eclipsed,[177] will be measured with precision only by the man who is equipped with your telescope and acquires skill in observing.

Therefore let Galileo take his stand by Kepler's side. Let the former observe the moon with his face turned skyward, while the latter studies the sun by looking down at a screen[178] (lest the lens injure his eye).[179] Let each employ his own device, and from this partnership may there some day arise an absolutely perfect theory of the distances.

By the help of my device I have seen (in addition to the moon) Mercury in the sun's disk; consult the little work which I published on this subject.[180]

If a comet appears, it will be possible to make highly accurate observations of its parallax (like the moon's) by comparison with those quite minute and very numerous stars which are visible only through your instrument. From the parallax measurements we may draw more definite conclusions than we have ever had before about the height of comets.[181]

It has been a pleasure, Galileo, to discuss with you these topics in the first section of your little book.

V

In the second section you turn to very important lunar phenomena. Your remarks remind me of what I said, on the basis of Plutarch, Mästlin, and my own observations, in my "Optical Part of Astronomy," Chapter VI, "The Light of the Heavenly Bodies," Number 9, "The Spots on the Moon."[182]

In the first place, it is a highly agreeable circumstance that I too engaged in observing the spots on the moon, not like you with upturned face, but with my head down. You will find a sketch[183] of this observation on page 247[184] of my book. It shows that the moon's limb[185] appeared very bright all around to me also,[186] only the interior of the body being marked by spots.

Hence it occurs to me to compete with you in scrutinizing those small spots first noticed by you in the brighter region.[187] Yet, if this is agreed upon, I hope to get results by my own method of observation, with my back to the moon. I shall admit the light of the moon through an aperture to a sheet of paper mounted on a rod. The aperture will be fitted with a crystal lens curving spherically from a circular edge. The paper will be adjusted to the focus of the rays. In this way, with a rod 12 feet long, a perfect image of the body of the moon will be obtained the size of a large silver coin. I explained the device in Proposition 23 on page 196 of my book,[188] and on page 211.[189] But a simpler form was suggested by Della Porta in the first article of Chapter VI,[190] where he introduced a lens,[191] whereas I dealt with an entire sphere.[192]

Let us proceed, Galileo, with the investigation of your phenomena. For you begin your observations by specifying the age of the moon, and for the first time you point out the imperfections of the oval line in the crescent phase.[193] In Number 8 on page 244 of my book I showed that the circle of illumination appears as an oval.[194] What you say, then, is correct and in full accord with mathematics.

In your discussion of the spots first noticed by you in the bright region of the moon, you show in a thorough optical analysis of the illumination that they are hollow or sunken cavities in the body of the moon. But you provoke a dispute over the nature of those numerous spots in what has been regarded from ancient times as the bright region of the moon. You compare them with the valleys on our earth.[195] There are some valleys of this kind, I admit, especially in the province of Styria.[196] They are almost round in appearance. Through very narrow[197] passes they admit the Mur River at their upper end, and discharge it at their lower end. Such are the so-called Fields of Graz, Leibniz, and Maribor on the Drava. There are others in other regions. Round about these fields rise the lofty summits of mountains, creating the impression of a bowl,[198] since the height of the surrounding peaks is no small fraction of the width of the fields. For my part I concede the possibility of such lunar valleys, carved by rivers[199] from the curving slopes of the mountains. But these spots are so numerous, you add, that they make the bright part of the body of the moon resemble a peacock's tail, divided into various eye-shaped reflecting surfaces.[200] Hence the question occurs to me whether these spots on the moon indicate something else. For among us on the earth there are some curving valleys, but they are also extensive in length, according to the course of the rivers, and of no mean depth. An example of this sort of virtually uninterrupted valley is offered by almost the whole of Austria, which, on account of[201] the Danube, lies deep and, as it were, hidden between the mountains of Moravia and Styria. Why then do you report no such long spots on the moon? Why are they for the most part[202] bounded by a circle? May I indulge in the guess that the moon is like pumice, with very many pores of the largest size opening up on all sides?[203] For you will patiently permit me here to take the opportunity to make some reference to the speculations set forth in Chapter 34, page 175,[204] of my "Commentary on Mars." I pointed out there that the moon is set in motion by the earth with twice the velocity of the outlying areas of the earth at the equator. Hence I inferred that the body of the moon is not very dense and that, possessing the slight resistance of a thin material, it offers no great opposition to the force exerted by the earth.[205]

But these suggestions (about cavities that are below the surface and not cut through the mountains)[206] are not so weighty that I would deem them worthy of a stubborn defense, should they be rendered completely untenable by your subsequent reports. For you have established most firmly by brilliant observations in full accord with the laws of optics that many peaks tower above the body of the moon, throughout the bright region, especially in the lower portion.[207] Like the loftiest mountains on our earth, they are the first to enjoy the light of the sun as it rises for the moon, and are thereby revealed to you when you make use of your telescope.

What shall I say now about your very acute analysis of the ancient spots on the moon? On page 251 of my book[208] I cited the opinion of Plutarch, who regarded those ancient spots on the moon as lakes or seas,[209] and the bright areas as continents. I did not hesitate to oppose him and to reverse his interpretation, by attributing the spots to continents, and the purity of the bright region to the effects of a liquid.[210] Wackher used to give strong approval to my stand on this question. We were deeply engaged in these discussions last summer[211] (I suppose, because nature was seeking the same results through us as it achieved a little later through Galileo). To please Wackher, I even founded a new astronomy for the inhabitants of the moon, as it were; in plain language, a sort of lunar geography. Among its basic propositions was this thesis, that the spots are continents, while the bright areas are seas.[212] My motive in contradicting Plutarch in this regard may be seen on page 251 of my book.[213] I there report an observation which I performed on Mt. Schöckel in Styria. From my vantage point the river below looked bright, and the land darker.[214] But the flaw in my reasoning is indicated in the margin of the very next page.[215] Obviously the river did not, like the land, shine by light received from the sun, but by light reflected from the illuminated air. Hence my analysis of the causes of the phenomenon was also unfortunate.[216] For, in opposition to the doctrine of Aristotle's book "On Colors,"[217] I asserted that water partakes of black less than earth does.[218] Yet how could this be true, since earth turns darker when it is soaked with water? But why go on at length? Suppose that the moon, like the island of Crete, is composed of a white soil (as Lucian[219] said that the moon[220] is a cheese-like land).[221] We shall have to admit that the soil shines by sunlight more vividly than the seas, however little they may be tinged with black.

My book, consequently, does not prevent me from agreeing with you, as you adduce mathematical arguments against me in favor of Plutarch with brilliant and irrefutable logic. Certainly the bright areas are broken up by many cavities; the bright areas are bounded by an irregular line; the bright areas contain great peaks, on account of which they light up sooner than the neighboring region. Where they face the sun, they are bright; where they face away from the sun, they are dark. All these characteristics suit a dry, solid, and high material, but not a fluid. On the other hand, the dark spots, known since antiquity, are flat. The dark spots light up later—a fact which proves their low[222] elevation—when the surrounding peaks are already aglow far and wide. When the dark spots are illumined, a certain shadow-like black effect differentiates them from the peaks.[223] The boundary of the illumination in the dark area is a straight line at half-moon. These characteristics, in turn, belong to a liquid, which seeks the lowest levels and on account of its weight settles in a horizontal position.

By these arguments, I say, you have proved your point completely. I admit that the spots are seas,[224] I admit that the bright areas are land.

These very acute observations of yours do not lack the support of even my own testimony. For on page 248 of my "Optics"[225] you have the half-moon divided by a wavy line. From this fact I deduced peaks and depressions in the body of the moon.[226] On page 250[227] I describe the moon during an eclipse as looking like torn flesh or broken wood, with bright streaks penetrating into the region in shadow.[228] On the basis of this observation I establish the conclusion, identical with yours, yet reached by a different sort of reasoning, that the parts of the moon are uneven, some being higher and others lower. I did not at that time[229] take into account the casting of a shadow. My thought was, instead, that some parts of the moon bordering the eclipsed area receive and reflect the diminished sunlight more powerfully, others more feebly.[230] I made these suggestions, however, only in a confused and superficial way, without distinguishing between the spots and the bright region. But under your skillful handling how simple everything becomes! You show that even the ancient spots themselves are sprinkled with small, level, whitish areas,[231] like seas dotted with conspicuous[232] islands.

I cannot help wondering about the meaning of that large circular cavity[233] in what I usually call the left corner of the mouth. Is it a work of nature, or of a trained hand? Suppose that there are living beings on the moon (following in the footsteps of Pythagoras[234] and Plutarch,[235] I enjoyed toying with this idea, long ago in a disputation written[236] at Tübingen in the year 1593,[237] later on in my "Optics" on page 250,[238] and most recently in my aforementioned lunar geography).[239] It surely stands to reason that the inhabitants express the character of their dwelling place, which has much bigger mountains and valleys than our earth has.[240] Consequently, being endowed with very massive bodies, they also construct gigantic projects. Their day is as long as 15 of our days,[241] and they feel insufferable heat. Perhaps they lack stone for erecting shelters against the sun. On the other hand, maybe they have a soil as sticky as clay. Their usual building plan, accordingly, is as follows. Digging up huge fields, they carry out the earth and heap it in a circle, perhaps for the purpose of drawing out the moisture down below. In this way they may hide deep in the shade behind their excavated mounds and, in keeping with the sun's motion, shift about inside, clinging to the shadow. They have, as it were, a sort of underground city. They make their homes in numerous caves hewn out of that circular embankment. They place their fields and pastures in the middle, to avoid being forced to go too far away from their farms in their flight from the sun.

But let us follow the thread of your discourse still further. You ask why the moon's outermost circle does not also appear irregular.[242] I do not know how carefully you have thought about this subject, or whether your query, as is more likely, is based on the popular impression. For in my book, on page 249[243] and page 250,[244] I stated that there was surely some imperfection in this outermost circle during full moon. Study the matter, and once again tell us how it looks to you, for I shall have confidence in your telescopes.

Assuming the fact to be established, you answer the question in two ways. The first way is not incompatible with my findings. For the multitude of peaks, crowded one behind another, presents the appearance of a perfect circle at the outermost limb of the visible hemisphere.[245] This can happen only if the peaks have been smoothed and polished on a lathe so that any tiny crevices or bumps fail to show up.[246] This situation would be consistent with my observations.

Your second way of answering the question is to wrap a sphere of air around the moon. Where this sphere curves back to the recesses of the lunar globe, it presents some depth to the rays from the sun and the earth, and thus to our eyes also. Hence the limb gleams pure and spotless, while the entire interior[247] of the face, where this air does not obstruct our vision so deeply, abounds with numerous spots.[248]

Pages 252 and 302 of my book[249] could have told you about this air on the moon.[250] These passages in my book are splendidly confirmed by your pertinent observations. I certainly do not understand how those inhabitants of the moon can bear the sun's terrific heat at full moon, which we see when it is high noon for them (and the same holds true for the others on the invisible hemisphere at new moon), unless the dense air covers the sun for them frequently, as happens among the Peruvians,[251] and moderates the heat with its moisture. At full moon this air hides the spots to a greater degree and, absorbing an intense brilliance from the sun, reflects it to us.[252]

While you talk about air around the moon, according to a little book[253] published at Tübingen in the year 1606 Mästlin even saw rain on the moon. For this is what he says in Thesis 152:

> The moon was eclipsed during the evening of Palm Sunday in the year 1605. On the body of the moon, in the north, a certain blackish spot was seen, darker than all the rest of the body, which looked like red-hot iron.[254] You might have called the spot a cloud, which was spread over a wide area and laden with rain and stormy showers. This kind of formation may be seen not infrequently stretching from the lofty mountain chains to the lower depths of the valleys.

This is what Mästlin says. But do not suppose that this was one of the ancient spots. Mästlin himself showed me a drawing of it last year.[255] The spot was different both in position and size, for it occupied about ¼ or ⅕ of the lunar surface, and besides was so black that it stood out even in the darkened moon.

In that little book, from Thesis 88 on,[256] he discusses the kinship of the moon with the earth on the basis of their density, shadow, atmosphere, and light borrowed from the sun. This light surrounds both globes. It reveals the phases of the moon to the inhabitants of the earth, and the corresponding phases of the earth to the inhabitants of the moon. Each body, then, receives light in the same way from the other. In this respect he agrees with a good part of my "Lunar Astronomy."[257] In Thesis 92 he finds another bond of kinship between these bodies in the roughness of their surfaces. It is noteworthy that he cites from three passages in Averroes what Aristotle says in his book on "Animals": "the moon has a high degree of affinity with the nature of the earth."[258]

In particular, beginning with Thesis 145,[259] he deals explicitly with the air circulating around the body of the moon. His language in Thesis 149 is so much like your own words, Galileo, that it seems to be taken from your little book:

> Scrutinize the body of the moon closely [he says] at any phase whatever. You will observe the outermost edge shining with a much clearer and purer light, and not besprinkled with any spots. In the interior of the body, however, very many darkish blotches are conspicuous everywhere. Who then will say that beneath the uniform light of the former extends nothing but the matter underlying the darker, dappled, and speckled splendor of the latter?

Hence he concludes that the material at the limb[260] is transparent, as though made of glass, airy, and homogeneous, in short, quite similar to the air around our earth.

Indeed, he devotes much space[261] to proving the existence of this air, as you do, Galileo,[262] by the following evidence: "the portion that is bathed in sunlight appears to have a larger circumference than the rest of the globe, which is in shadow." Mästlin demonstrates this by many observations. These were performed not only at night, when[263] the explanation might be referred to the conditions of seeing, but also by day, when Venus disappears behind the part of the half-moon[264] that is in shadow. Yet even though[265] I admit a lunar[266] atmosphere, may I nevertheless, with your permission, adhere to the following interpretation of this observation: the moon's light, on the one side, and the planet's light, on the other, even in the daytime are dilated in the eye and encroach upon the space of the region in shadow so that it[267] is adjudged small, but the bright area, large. See my "Optics," page 217.[268]

The next item in your little book is the ingenious and sound proof on page 13[269] of what I too mentioned casually[270] on page 250, but failed to demonstrate. The mountains on the moon are much bigger than those on the earth, not merely in relation to their globes, as I put it,[271] but absolutely. In order to prove this proposition, of course, your telescope was needed, and your observational skill.

No less ingenious is your arrangement on page 14[272] for inspecting the disk of the moon when its horns first emerge. You explain how to observe from behind a roof so that the horns are covered up and the rest of the disk becomes visible. This is an observational method very familiar to me.

But the proof that this light is derived from our earth was already known to Mästlin 20 or more years ago. I transferred it from his exposition to my "Optical Part of Astronomy," Chapter 6, Number 10, page 252,[273] with a very full discussion. There, adopting a procedure identical with yours, I too reject the same suppositions (that this light comes from the sun or[274] from Venus), except that I treat the latter conjecture on its merits somewhat more favorably than you do.[275]

When the moon is in eclipse, it retains a coppery redness around the edges of the earth's shadow, while the rest of the body vanishes in darkness. On page 15[276] you attribute this color to the illumination of the adjacent aether-like substance. You support my discussion of this redness on page 271 of the "Optics,"[277] where I derive it from the refraction of the sun's rays in our atmosphere.[278] You also enhance the usefulness of what I said on page 301[279] by way of explaining[280] why complete darkness does not always occur during a total eclipse of the sun;[281] I repeated these remarks on page 117 in my book on the "New Star."[282] I doubt, Galileo, whether the cause proposed[283] by you can account for this redness. For this dawn-light, as you call it,[284] surrounds the body of the moon much too uniformly to be the source of the redness, which is distributed so unevenly over the moon. This is shown by my observations, as reported on page 276.[285] When you consider this subject in your "System of the Universe,"[286] you will, I trust, advance a much more successful explanation of the causes of the phenomena under discussion.

But the situation is otherwise with respect to the pale light produced on that portion of the moon which lies in deep shadow, where the refracted sunbeams fail to penetrate. I readily grant that, as compared with the celestial bodies in the vicinity of the sun, which I regarded on page 277[287] as the cause of the pale light, this dawn-light of yours serves as a better explanation.

VI

Having finished the second section of your little book, where you deal with the moon, I pass on to the third section, treating the other heavenly bodies.

Your first observation concerns the size of the stars and planets. When their small bodies are examined through the telescope, you say that they shrink[288] in comparison with the diameter of the moon. You also mention other things, which truly produce a similar diminution of the stars, as I have known from long experience: twilight, daylight, a cloud, a veil, colored glass.[289]

Now I quote your words: "The angle subtended at the eye is determined not by the primary disk of the star, but by the brightness which so widely surrounds it;" also, "The telescope removes from the stars their adventitious and accidental splendors."[290]

I should like to ask you, Galileo, whether you are satisfied with the reasons for this effect, as presented by me in my discussion of the process of vision on page 217[291] and especially on page 221 of my "Optics."[292] For if you find nothing amiss, you may hereafter discuss the matter correctly.[293] Point sources of light transmit their cones to the crystalline lens. There refraction takes place, and behind the lens the cones again contract to a point. But this point does not reach as far as the retina. Therefore the light is dispersed once more, and spreads over a small area of the retina, whereas it should impinge on a point. Hence the telescope, by introducing another refraction, makes this point coincide with the retina. It is not true, then, that some rays come down to the eye from the brightness enveloping the stars on the outside. On the contrary, the rays which come down from the shining body itself are scattered, as a result of refraction and the widening of the opening in the uvea at night. They brighten the area on the retina around the point which should represent the star. The telescope on earth does not remove anything from the stars in heaven, but it does take away from the retina whatever light is superfluous.

Your second highly welcome observation concerns the sparkling appearance of the fixed stars, in contrast with the circular appearance of the planets.[294] What other conclusion shall we draw from this difference, Galileo, than that the fixed stars generate their light from within, whereas the planets, being opaque, are illuminated from without; that is, to use Bruno's terms, the former are suns,[295] the latter, moons or earths?[296]

Nevertheless, let him not lead us on to his belief in infinite worlds, as numerous as the fixed stars and all similar to our own.[297] Your third observation comes to our support: the countless host of fixed stars exceeds what was known in antiquity.[298] You do not hesitate to declare that there are visible over 10,000 stars.[299] The more there are, and the more crowded they are, the stronger becomes my argument against the infinity of the universe, as set forth in my book on the "New Star," Chapter 21, page 104.[300] This argument proves that where we mortals dwell, in the company of the sun and the planets, is the primary bosom of the universe; from none of the fixed stars can such a view of the universe be obtained as is possible from our earth or even from the sun. For the sake of brevity, I forbear to summarize the passage. Whoever reads it in its entirety will be inclined to assent.[301]

Let me add this consideration to buttress my case. To my weak eyes,[302] any of the larger[303] stars, such as Sirius, if I take its flashing rays into account, seems to be only a little smaller than the diameter of the moon. But persons with unimpaired vision, using astronomical instruments that are not deceived by these wavy crowns, as is the naked eye, ascertain the dimensions of the stars' diameters in terms of minutes and fractions of minutes. Suppose that we took only 1000[304] fixed stars, none of them larger than 1′ (yet the majority in the catalogues are larger). If these were all merged in a single round surface, they would equal (and even surpass) the diameter of the sun. If the little disks of 10,000 stars are fused into one, how much more will their visible size exceed[305] the apparent disk of the sun? If this is true, and if they are suns having the same nature as our sun, why do not these suns collectively outdistance our sun in brilliance? Why do they all together transmit so dim a light to the most accessible places? When sunlight bursts into a sealed room through a hole made with a tiny pin point, it outshines the fixed stars at once. The difference is practically infinite; if the whole room were removed, how great would it become?[306] Will my opponent tell me that the stars are very far away from us? This does not help his cause at all. For the greater their distance, the more does every single one of them outstrip the sun in diameter. But maybe the intervening aether obscures them? Not in the least. For we see them with their sparkling, with their various shapes and colors.[307] This could not happen if the density of the aether offered any obstacle.

Hence it is quite clear that the body of our sun is brighter beyond measure than all the fixed stars together, and therefore this world of ours does not belong to an undifferentiated swarm of countless others. I shall have more to say about this subject later on.[308]

You have a large number of eyewitnesses to the innumerability of the stars. The rabbis are said[309] to enumerate more than 12,000. A clergyman[310] of my acquaintance one moonless night counted over 40 in Orion's Shield. The larger stars in the Pleiades are arranged in order by Mästlin to the number of fourteen, if I am not mistaken, none of them below the limits of the traditional magnitudes.[311]

VII

You have conferred a blessing on astronomers and physicists by revealing the true character of the Milky Way, the nebulae, and the nebulous spirals.[312] You have upheld those writers who long ago reached the same conclusion as you: they are nothing but a mass of stars, whose luminosities blend[313] on account of the dullness of our eyes.

Accordingly, scientists will henceforth cease to create comets and new stars out of the Milky Way, after the manner of Brahe,[314] lest they irrationally assert the passing away of perfect and eternal celestial bodies.

VIII

Finally I move on with you to the new planets, the most wonderful topic in your little book. On this subject I shall say only a few words to you in addition to what I wrote at the outset.[315]

In the first place, I rejoice that I am to some extent restored to life[316] by your work. If you had discovered any planets revolving around one of the fixed stars, there would now be waiting for me chains and a prison[317] amid Bruno's innumerabilities, I should rather say, exile to his infinite space. Therefore, by reporting that these four planets revolve, not around one of the fixed stars, but around the planet Jupiter, you have for the present[318] freed me from the great fear which gripped me as soon as I had heard about your book from my opponent's triumphal shout.

Wackher of course had once more[319] been seized by deep admiration for that dreadful[320] philosophy. What Galileo recently saw with his own eyes, it had many years before not only proposed as a surmise, but thoroughly established by reasoning. It is doubtless with perfect justice that those men attain fame whose intellect anticipates the senses in closely related branches of philosophy. Theoretical astronomy, at a time when it had never set foot outside Greece, nevertheless disclosed the characteristics of the Arctic Zone.[321] Who then would not rank it in nobility above Caesar's experience of learning from the water-clocks that the nights on the coasts of Britain are a little shorter than the nights in Rome,[322] or above the Dutchmen's spending the winter in the north,[323] an expedition which was indeed wonderful, but which would have been impossible without that theoretical knowledge? Who does not honor Plato's myth of Atlantis,[324] Plutarch's legend of the gold-colored islands beyond Thule,[325] and Seneca's prophetic verses about the forthcoming discovery of a New World,[326] now that the evidence for such a place has finally been furnished by that Argonaut from Florence?[327] Columbus himself keeps his readers uncertain[328] whether to admire his intellect in divining the New World from the direction of the winds, more than his courage in facing unknown seas and the boundless ocean, and his good luck in gaining his objective.

In my own field too, the prodigies will naturally be Pythagoras,[329] Plato,[330] and Euclid.[331] Borne aloft by the preeminence of their reason, they argued that God could not have done otherwise than to arrange the world on the model of the five regular solids. But they mistook the pattern. On the other hand, the plaudits of the average man will go to Copernicus who, equipped with a mind that was not average, yet drew a picture of the universe virtually[332] as it is seen by the eye. But he brought to light only the bare facts. Trailing far behind the ancients will be Kepler. From the visual outlook of the Copernican system he rises, as it were, from the facts to the causes, and to the same explanation[333] as Plato from on high had set forth deductively so many centuries before. He shows that the Copernican system of the world exhibits the reason for the five Platonic solids. It is not an act of folly or jealousy to set the ancients above the moderns; the very nature of the subject demands it. For the glory of the Creator of this world is greater than that of the student of the world, however ingenious. The former brought forth the structural design from within himself, whereas the latter, despite strenuous efforts, scarcely perceives the plan embodied in the structure. Surely those thinkers who intellectually grasp the causes of phenomena, before these are revealed to the senses, resemble the Creator more closely than the others, who speculate about the causes after the phenomena have been seen.

Therefore, Galileo, you will not envy our predecessors their due praise. What you report as having been quite recently observed by your own eyes, they predicted, long before you, as necessarily so. Nevertheless, you will have your own fame. Copernicus and I, as a Copernican, pointed out to the ancients the mistaken way in which they considered the five solids to be expressed in the world, and we[334] substituted the authentic and true way. Similarly, you correct and, in part, unsettle[335] Bruce's doctrine, borrowed[336] from Bruno. These men thought that other celestial bodies have their own moons revolving around them, like our earth with its moon. But you prove that they were talking in generalities. Moreover, they supposed it was the fixed stars that are so accompanied.[337] Bruno even expounded the reason why this must be so. The fixed stars, forsooth, have the quality of sun and fire, but the planets, of water. By an indefeasible law of nature these opposites combine. The sun cannot be deprived of the planets; the fire, of its water; nor in turn the water, of the fire.[338] Now the weakness of his reasoning[339] is exposed by your observations. In the first place, suppose that each and every fixed star is a sun. No moons have yet been seen revolving around them. Hence this will remain an open question until this phenomenon too is detected by someone equipped for marvelously refined observations. At any rate, this is what your success threatens us with, in the judgment of certain persons.[340] On the other hand, Jupiter is one of the planets, which Bruno describes as earths.[341] And behold, there are four other planets around Jupiter.[342] Yet Bruno's argument made this claim not for the earths, but for the suns.[343]

Meanwhile I cannot refrain from contributing this additional feature to the unorthodox aspects of your findings. It is not improbable, I must point out,[344] that there are inhabitants not only on the moon but on Jupiter too or (as was delightfully remarked at a recent gathering of certain philosophers[345]) that those areas are now being unveiled for the first time. But as soon as somebody demonstrates the art of flying, settlers from our species of man will not be lacking. Who would once have thought that the crossing of the wide ocean was calmer and safer[346] than of the narrow Adriatic Sea, Baltic Sea, or English Channel? Given ships or sails adapted to the breezes of heaven, there will be those who will not shrink from even that vast expanse. Therefore, for the sake of those who, as it were, will presently be on hand to attempt this voyage, let us establish the astronomy, Galileo, you of Jupiter, and me of the moon.

Let the foregoing pleasantries be inserted on account of the miracle of human courage, which is evident in the men of the present age especially. For the revered mysteries of sacred history are not a laughing matter for me.

I have also thought it worth while, in passing, to tweak the ear of the higher philosophy. Let it ponder the questions whether the almighty and provident Guardian of the human race permits anything useless and why, like an experienced steward, He opens the inner chambers of his building to us at this particular time. Such was the opinion put forward by my good friend Thomas Seget,[347] a man of wide learning. Or does God the creator, as I replied, lead mankind, like some growing youngster gradually approaching maturity, step by step from one stage of knowledge to another? (For example, there was a period when the distinction between the planets and the fixed stars was unknown;[348] it was quite some time before Pythagoras or Parmenides perceived that the evening star and the morning star are the same body;[349] the planets are not mentioned in Moses,[350] Job,[351] or the Psalms[352]). Let the higher philosophy reflect, I repeat, and glance backward to some extent. How far has the knowledge of nature progressed, how much is left, and what may the men of the future expect?

But let us return to humbler thoughts, and finish what we began. There are in fact four planets revolving around Jupiter at different distances with unequal periods.[353] For whose sake, the question arises, if there are no people on Jupiter to behold this wonderfully varied display with their own eyes? For, as far as we on the earth are concerned, I do not know by what arguments I may be persuaded to believe that these planets minister chiefly to us, who never see them. We should not anticipate that all of us, equipped with your telescopes, Galileo, will observe them hereafter as a matter of course.

This is the proper place, I think, to face a certain other criticism. Will some people regard our earthly astrology, or to speak technically, our doctrine of aspects,[354] as false, because up to this very day we have erred regarding the number of planets constituting the aspects? Yet they are wrong, since the planets affect us by the way in which their impulses reach the earth. For they operate through the aspects, and an aspect is a disposition produced by the angle formed at the center of the earth or of the eye. Obviously the planets themselves do not act on us, but their aspects become, by influence alone, bridle and spur for those minds on earth that partake of the principle involved.

Now it is clear from your observations, Galileo, that these four planets are very tiny and never diverge more than 14′ from Jupiter.[355] Hence the entire orbit of the outermost planet is smaller than the disk of the sun or the moon.[356] I am prepared to admit that, since their minute size offers no obstacle, they coincide in the aspects for influencing terrestrial minds. Even so, the four of them together with Jupiter, the center of their revolutions, will not be able, on account of the width of their diameter, to accomplish anything more than jointly to match the sun (and this not frequently) in some enduring aspect.

In this way astrology maintains its standing.[357] At the same time it becomes evident that these four new planets were ordained not primarily for us who live on the earth, but undoubtedly for the Jovian beings who dwell around Jupiter.

This conclusion is more obvious to those who, together with you, Galileo,[358] and with me, accept Copernicus' system of the universe. For we see the moon so arranged therein that, as a planet revolving around the earth, it cannot appear to be intended for other globes, but only for the earth, which it encircles as it moves. The diameter of its path is considered to be $\frac{1}{20}$ of the diameter of the earth's "great circle"[359] around the sun,[360] but I believe it is hardly $\frac{1}{30}$.[361] Hence, as seen from the sun, it subtends less than 3°,[362] or on my figures, less than 2°.[363] Now Saturn is 10 times more remote,[364] and Jupiter about 5.[365] Therefore, as seen from Saturn,[366] our moon cannot diverge more than 18′[367] or 12′[368] from the earth; as seen from Jupiter, about 36′[369] or 24′.[370] Thus it is related to the inhabitants[371] of Saturn and Jupiter precisely as Jupiter's satellites[372] are to us, the creatures of earth. A comparison of sizes leads to the same result. Assume that the solar parallax is 3′,[373] although I think it is much less.[374] Then the earth, as seen from the sun, will be 6′,[375] and the moon, 1.5′.[376] But since the earth is much smaller, it will reduce the moon also, surely to below 1′. This will look like perhaps 6″, as seen from Saturn,[377] 12″ from Jupiter.[378] The conclusion is quite clear. Our moon exists for us on the earth, not for the other globes. Those four little moons exist for Jupiter, not for us. Each planet in turn, together with its occupants, is served by its own satellites. From this line of reasoning we deduce with the highest degree of probability that Jupiter is inhabited. Tycho Brahe likewise drew the same inference, based exclusively on a consideration of the hugeness of those globes.[379]

A further consequence was very brilliantly pointed out by Wackher. Like our earth, Jupiter also rotates about its axis.[380] That rotation is accompanied by the revolution of the four moons, just as the rotation of our earth is accompanied by the revolution of our moon in the same direction.[381] Therefore Wackher now finally accepts the magnetic principles by which, in my recent "Commentary on Celestial Physics," I explained that the motions of the planets are caused by the rotation of the sun about its axis and poles.[382]

While Jupiter moves along its 12-year orbit, four satellites encompass it before and behind. What was absurd, then, in Copernicus' statement[383] (as you neatly remark, Galileo[384]) that while the earth performs its annual revolution, a single moon clings to it in the same way?[385]

Well, then, someone may say, if there are globes in the heaven similar to our earth, do we vie with them over who occupies the better portion of the universe? For if their globes are nobler, we are not the noblest of rational creatures. Then how can all things be for man's sake? How can we be the masters of God's handiwork?

It is difficult to unravel this knot, because we have not yet acquired all the relevant information. We shall hardly escape being labeled foolish if we expatiate at length on this subject.

Yet I shall not pass over in silence those philosophical arguments which, it seems to me, can be brought to bear. They will establish not merely in general, as was done above,[386] that this system of planets, on one of which we humans dwell, is located in the very bosom of the world, around the heart of the universe, that is, the sun. These arguments will also establish in particular that we humans live on the globe which by right belongs to the primary rational creature, the noblest of the (corporeal) creatures.

In support of the former proposition concerning the inmost bosom of the world, see the evidence cited above.[387] It was based, first, on the fixed stars, which by their vast numbers truly enclose this area like a wall and, secondly, on our sun, which is more splendid than the fixed stars. To the foregoing may be added a third consideration, which Wackher elicited[388] from me during the past few days, and to which he seemed by his silence to assent.

Geometry is unique and eternal, and it shines in the mind of God. The share of it which has been granted to man is one of the reasons why he is the image of God. Now in geometry the most perfect class of figures, after the sphere,[389] consists of the five Euclidean solids. They constitute the very pattern and model according to which this planetary world of ours was apportioned. Suppose then that there is an unlimited number of other worlds. They will be either unlike ours or like it. You would not say, "like it." For what is the use of an unlimited number of worlds, if every single one of them contains all of perfection within itself? Surely the situation is different with regard to the creatures which perpetuate themselves by a succession of generations. Even Bruno, the defender of infinity, holds that each world must differ from the rest[390] in the kinds of motion, although these are of like number. If the worlds differ in their motions, then they must differ also in their distances, which determine the periods of the motions. If they differ in their distances, then they must differ also in the arrangement, type, and perfection of their solids, from which the distances are derived. Indeed, if you establish universes similar to one another in all respects, you will also produce similar creatures, and as many Galileos, observing new stars in new worlds, as there are worlds. But of what use is this? Briefly, it is better to avoid the march to the infinite permitted by the philosophers.[391] Since it is agreed that there is a limit to the regress in the direction of the smaller,[392] why not also in the direction of the larger? For example, take the sphere of the fixed stars. One three-thousandth part of it, perhaps, is the sphere of Saturn.[393] Of this, in turn, 1/10th part is the sphere of the earth.[394] One three-hundred-thousandth part of the earth's diameter,[395] again, is man. A tiny part of man is the little pore beneath his skin. Here we stop. Nature goes no lower.[396] Now let us tackle the other horn of the dilemma. Suppose those infinite worlds are unlike ours. Then they will be supplied with something different from the five perfect solids. Hence they will be less noble than our world. Therefore it follows that this world of ours is the most excellent of them all, if there should be a plurality of worlds.

Let us now also indicate why the earth surpasses Jupiter and better deserves to be the abode of the predominant creature.

In the center of the world is the sun, heart of the universe, fountain of light, source of heat, origin of life and cosmic motion. But it seems that man ought quietly to shun that royal throne. Heaven was assigned to the lord of heaven, the sun of righteousness;[397] but earth, to the children of man. God has no body, of course, and requires no dwelling place. Yet more of the force which rules the world is revealed in the sun (in the heaven, as various passages of Scripture put it[398]) than in all the other globes. Because man's house is otherwise, therefore, let him recognize his own wretchedness and the opulence of God. Let him acknowledge that he is not the source and origin of the world's splendor, but that he is dependent on the true source and origin thereof. Moreover, as I said in the "Optics," in the interests of that contemplation for which man was created, and adorned and equipped with eyes, he could not remain at rest in the center. On the contrary, he must make an annual journey on this boat, which is our earth, to perform his observations. So surveyors, in measuring inaccessible objects, move from place to place for the purpose of obtaining from the distance between their positions an accurate base line for the triangulation.[399]

After the sun, however, there is no globe nobler or more suitable for man than the earth. For, in the first place, it is exactly in the middle of the principal globes (if we exclude, as we should, Jupiter's satellites and the moon revolving around the earth[400]). Above it are Mars, Jupiter, and Saturn. Within the embrace of its orbit run Venus and Mercury, while at the center the sun rotates,[401] instigator of all the motions, truly an Apollo, the term frequently used by Bruno.[402]

Secondly, the five solids divide into two groups: the three major bodies, cube, tetrahedron, and dodecahedron; and the two minor bodies, icosahedron and octahedron. The earth's orbit separates the two groups like a partition, by touching the centers of the 12 faces of the dodecahedron above it, and the 12 vertices of the corresponding icosahedron below it. Merely by its position amidst the solids, the sphere of the earth is more distinguished than the other spheres.

Thirdly, we on the earth have difficulty in seeing Mercury, the last of the principal planets, on account of the nearby, overpowering brilliance of the sun. From Jupiter or Saturn, how much less distinct will Mercury be? Hence this globe seems assigned to man with the express intent of enabling him to view all the planets. Will anyone then deny that, to make up for the planets concealed from the Jovians but visible to us earth-dwellers, four others are allocated to Jupiter, to match the four inferior planets, Mars, Earth, Venus, and Mercury, which revolve around the sun within Jupiter's orbit?

Let the Jovian creatures, therefore, have something with which to console themselves. Let them even have, if it seems right, their own four planets arranged in conformity with a group of three rhombic solids. Of these, one is the cube (a quasi-rhombic); the second is cuboctahedral; the third is icosidodecahedral; with 6, 12, and 30 quadrilateral faces, respectively.[403] Let the Jovians, I repeat, have their own planets. We humans who inhabit the earth can with good reason (in my view) feel proud of the pre-eminent lodging place of our bodies, and we should be grateful to God the creator.

I have enjoyed this philosophical discussion with you about the new questions raised by your observations, Galileo.

But having already mentioned rather frequently[404] how my "Cosmographic Mystery" builds up the universe by means of the five regular solids, I shall in a few words completely dispose of the difficulty mentioned at the beginning of this letter.[405]

These four planets revolve around Jupiter in very narrow orbits. But nobody need fear that they are going to disrupt my theory, according to which the solids of Pythagoras are inserted between the planets. On the contrary, I rather hope that these satellites of Jupiter, and those of the other planets, if they too have any, will finally remove the entire remaining discrepancy. For how God incorporated these satellites also in the arrangement of the solids is indicated by the earth's satellite, namely, the moon, whose revolution around the earth I could not ignore when I was earnestly[406] investigating that topic.

Even now, in revising the orbits and motions of Mars, Earth, and Venus on the basis of Brahe's observations, I notice that unexplained gaps persist. If the dodecahedron's vertices are pushed outward to meet Mars' perihelion, the centers of its faces do not reach the moon at apogee, with the earth at aphelion. If the icosahedron's centers are adjusted to Venus' aphelion, they do not carry the icosahedron's vertices out as far as the moon at apogee, with the earth at perihelion. This proves that there is some unoccupied space between Mars' perihelion and the dodecahedron's vertices, and likewise between the icosahedron's centers and Venus' aphelion. It is remarkable that the former interval somewhat exceeds the latter. In these small areas I hope quite easily to fit the moons of Mars and Venus, if some day you find any,[407] Galileo.

IX

With you, Galileo, I began; with you, I shall end. You have good reason to wonder why the Medicean planets display so great a variation in size.[408] Three explanations which anybody could invent, you refute neatly and mathematically.[409] You propose a physical cause as possible;[410] concerning this, time will tell. But the following thought occurs to me. Suppose that these four planets, looking like disks, revolve in a plane[411] tilted toward Jupiter.[412] Then in the outermost sections of their path they will be presented to us and the sun as lines. When above and below, they will be lighted perpendicularly. They will appear large, and will perhaps show various colors, in accordance with the difference in the planes. Let this do for a suggestion.[413]

It remains for me to make an urgent request of you, most illustrious Galileo. Press on vigorously with your observations, and let us know at the very earliest opportunity what results your observations have attained. Finally, forgive my diffuse and independent way of discussing nature. Farewell.

Prague,

April 19, 1610.

POSTSCRIPT[414]

If I had waited one more day,[415] I could have repaid the debt to Galileo. For the catalogue of the Frankfurt book fair announced something new. Unlike Galileo's material, which is plausible though unprecedented, this is, on the contrary, completely ridiculous though often bandied about. A certain Thomas Gephyrander has squared the circle.[416] No confirmation has as yet been placed before our eyes here, but reason shut our ears at the first report.

Another author, Wolfgang Sattler of Basel, issues a "Mercury"[417] (in olden times believed to be a messenger of the gods) to show[418] astrologers that an aspect of 30° has an effect. I congratulate him on his personal acquisition of the truth. In other regards the messenger is partly mistaken; thus, he is in error about the first discoverer. Mästlin made this point in his theses about the variety of motions, published in the year 1606.[419] I myself have used this aspect since the year 1603.[420] See my "Third Man in the Middle,"[421] available at this same book fair.[422] I called it the "semi-sextile."[423] A very delightful explanation of it is promised for my "Harmonics."[424]

NOTES

* *An asterisk at the end of a Note refers to a continuation in the Additional Notes beginning on page 155.*

1. "Le Opere di Galileo Galilei" (Florence, 1890–1909; reprinted, 1929–1939). This magnificent national edition in twenty volumes will be cited hereafter as "NE." The volume will be designated by a Roman numeral, whereas pages will be denoted by Arabic numbers, separated by a colon from other Arabic numbers referring to lines. Thus, the present passage will be found at NE III, 59:6.

2. See Edward Rosen, "The Title of Galileo's Sidereus nuncius," *Isis* **41,** 287–289 (1950), and *J. Hist. Ideas* **18,** 440–443 (1957). Kepler's misinterpretation of Galileo's title infected Edward Stafford Carlos' complete English translation of "The Sidereal Messenger of Galileo Galilei" (London, 1880; reissued, London: Dawson, 1960), and also the incomplete paraphrase in Stillman Drake, "Discoveries and Opinions of Galileo" (Garden City: Doubleday, 1957), pp. 21–58. Drake later contended (*Isis* **49,** 346–347, 1958) that Galileo, who despised ambiguity, deliberately chose an ambiguous title.

3. Giambatista Venturi, ed., "Memorie e lettere inedite finora o disperse di Galileo Galilei" (Modena, 1818–1821), I, 99.

4. Karl von Gebler, "Galileo Galilei und die römische Curie" (Stuttgart, 1876–1877), I, 28; translated into English by Mrs. George Sturge as "Galileo Galilei and the Roman Curia" (London, 1879), p. 22.

5. Grant McColley, *Ann. Sci.* **1,** 416 (1936). In *Smith College Studies Hist.* **22** (3–4), 11 (1937), McColley

presented "prefatory dissertation to the *Starry Messenger* of Galileo" as his English equivalent of "dissertatione super nuncio Galilei." But here "prefatory" is the merest intrusion, not justified by anything in this Latin expression used by Tommaso Campanella in his "Defence of Galileo" (Frankfurt, 1622, p. 10). In citing Kepler's title, it will be noticed, Campanella replaced "cum" by "super." In thus altering the preposition, Campanella revealed that he correctly understood the title of Galileo's "Message": Kepler could not conduct a conversation with ("cum") a message, but he could write a dissertation about ("super") it. Thinking along similar lines, Venturi (I, 144) substituted "de" for "cum" in the title of Kepler's "Dissertatio."

6. NE X, no. 297; here the letter is nearly 800 lines in length.

7. "Joannis Kepleri astronomi opera omnia," Christian Frisch, ed. (Frankfort on the Main and Erlangen, 1858–1871; cited hereafter as "F"), II, 485–506.

8. NE III, 97–125.

9. Johannes Kepler, "Gesammelte Werke" (Munich: Beck, 1937– ; cited hereafter as "GW"), IV, 281–311. Dr. Franz Hammer, who edited the "Conversation" in GW, listed the readings in which the letter of April 19 differs from the printed "Conversation" (GW IV, 506–507).

10. NE X, 459:87–88; GW XVI, 344:98–99.

11. GW XVI, no. 603:31–47; NE X, 507:28–41.

12. "The Sleepwalkers" (London: Hutchinson; New York: Macmillan; 1959), p. 371; "The Watershed" (Garden City: Doubleday, 1960; London: Heinemann, 1961), p. 192.

13. Otto J. Bryk, ed., Johann Kepler, "Die Zusammenklänge der Welten" (Jena, 1918; in the series "Klassiker der Naturwissenschaft und Technik," Franz Strunz, ed.), p. xxxvi.

14. In the Prague, 1610 edition a broad band of white space clearly indicates the place where Kepler passes from one topic to the next. I have introduced numbers for these nine sections in order to make it somewhat easier to locate any given passage in the "Conversation."

15. This substitution of "in" for Kepler's "cum" shows that Fugger too interpreted "nuncium" in Galileo's title correctly as "message."

16. GW XVI, no. 578:2–4; NE X, no. 319:2–4.

17. GW XVI, 302:14–18; NE X, no. 292:3–6.

18. See Edward Rosen, "Did Galileo Claim He Invented the Telescope?," *Proc. Am. Phil. Soc.* **98,** 304–312 (1954). In his introduction to George Gamow, "The Moon" (London and New York: Abelard-Schuman, 1953; rev. ed., 1959, p. 9), Harold C. Urey wrote: "Galileo invented the telescope in 1610." If the Nobel prize were granted for achievement in the history of science, such a misstatement would not have earned Dr. Urey his coveted award. According to Gamow (p. 72), "If Galileo had been able to see the surface of the moon as well as we can see it today, he certainly would never have given to that rugged plain the romantic name of the 'Sea of Showers.'" Actually the Mare Imbrium was so christened, not by Galileo, but by Giovanni Battista Riccioli, "New Almagest" (Bologna, 1651), I, 205.

19. This motto, with its emphasis on freedom of thought, served as a rallying cry for the advocates of the Copernican system in their challenge to the traditional cosmology. Kepler found the motto in the earliest printed exposition of the new system, the "First Account" ("Narratio prima") by George Joachim Rheticus [English translation in Edward Rosen, "Three Copernican Treatises," 2nd ed., 1959 (New York: Dover; London: Constable)]. Rheticus in turn had taken the motto from an elementary "Epitome of Plato's Teachings," which was available to him in several

editions of the original Greek as well as two translations into Latin. All these printed books, in agreement with all the manuscripts of the "Epitome," attributed the work to Alcinous. This attribution was accepted without any hesitation by both Rheticus and Kepler, neither of whom was aware that a confusion had occurred. The only Alcinous to whom the "Epitome" may be ascribed was a Stoic, whereas its author unquestionably was a Platonist. A considerable reputation as a commentator and lecturer on the Platonic philosophy was gained by Albinus. So long as writing was confined to capital letters, "Alcinous" would not have been substituted for "Albinus." But when lower-case letters were introduced in the ninth century, lower-case beta was at first sometimes mistaken for lower-case kappa. By this medieval confusion "Albinos" was transformed into "Alkinos," and this nonexistent form must have been subsequently made more palatable as "Alkinoos" (Alcinous). This end product of a double alteration in spelling was then named as the author of the "Epitome of Plato's Teachings" in the manuscript from which all the other manuscripts and all the printed editions are derived. Albinus was thereby deprived of the authorship of the "Epitome," which closely resembles his only other surviving writing, a brief "Introduction to Plato's Dialogues." In "Albinus and the History of Middle Platonism" (Cambridge Univ. Press, 1937) Reginald E. Witt showed that Plato was expounded by Albinus in a manner typical of his time, the middle of the second century after Christ. In Pierre Louis' edition of the Greek text, with a French translation on facing pages (Albinos, "Epitomé," Paris, 1945), the Rheticus-Kepler motto appears on pp. 4–5.

20. The press established at Prague in 1584 by this distinguished Czech printer remained in his family more than a century. Since he came from the town of Sedlčany, about 30 miles due south of Prague, he called himself Sedlčansky in Czech or Sedesanus in Latin (Paul Krasnopolski, "Prager Drucke bis 1620," *Gutenberg Jahrbuch*

1927, 82; Josef Volf, "Geschichte des Buchdrucks in Böhmen und Mähren bis 1848," Weimar, 1928, pp. 75–77).

21. Giuliano de' Medici (1574–1636) served as Tuscan ambassador to the Holy Roman Empire from 1608 to 1618.

22. Galileo taught mathematics at the University of Padua from 1592 to 1610.

23. Kepler says that Giuliano de' Medici sent ("transmisso") him a copy of Galileo's book. The ambassador did not merely show Kepler the book, despite Max Caspar (GW XVI, 451: gezeigt). Nor is it true that Kepler "received a copy of his own from Galileo," despite Koestler ("Sleepwalkers," p. 370; "Watershed," p. 192).

24. For this Scottish poet and amateur astronomer, who was a friend of both Galileo and Kepler, see Edward Rosen, "Thomas Seget of Seton," *Scot. Hist. Rev.* **28,** 91–95 (1949). Seget brought the ambassador's copy of Galileo's "Message" to Kepler on April 8, not April 13, despite Michael W. Burke-Gaffney, "Kepler and the Jesuits" (Milwaukee: Bruce, 1944), p. 64.

25. This letter from Galileo to Giuliano de' Medici has not survived. Nevertheless, despite its disappearance, what it requested of Kepler may be inferred from Kepler's reference to it later on in Section I of the "Conversation," near Note 82. There Kepler explicitly states that in the lost letter to Giuliano de' Medici, Galileo asked Kepler for a written expression of his reaction to Galileo's telescopic discoveries. That written expression became Kepler's "Conversation."

Since Kepler's "Conversation" was his response to Galileo's request, it should be noted that the request was read to him, according to his own statement in the Dedication, on April 13. Kepler did not receive Galileo's request on April 8, despite Hammer (GW IV, 449), Caspar, "Johannes Kepler," 3rd ed. (Stuttgart, 1958), p. 221 (translated into English by C. Doris Hellman, London and New

York: Abelard-Schuman, 1959, p. 192), and Koestler ("Sleepwalkers," p. 370; "Watershed," p. 192). On April 8 Kepler received the copy of Galileo's book which the author had sent to Giuliano de' Medici, and which the ambassador in turn passed on to Kepler through Seget on April 8. But on that day nothing was said to Kepler about Galileo's request. He heard nothing about that request until it was read to him by the ambassador himself on April 13.

This difference of five days has an important bearing on the speed with which Kepler wrote the "Conversation." In the Notice to the Reader Kepler himself says that he composed the "Conversation" "in great haste." Since he finished it on April 19 in response to a request which he first heard on April 13, he wrote it in a week. Hence he did not draft it in eleven days, April 8–19, despite Hammer (GW IV, 450), Caspar ("Kepler," p. 221; Caspar-Hellman, p. 192), and Koestler ("Sleepwalkers," p. 370; "Watershed," p. 192). True, he received the ambassador's copy of Galileo's book on April 8. But he had already seen the emperor's copy, and been ordered by the emperor to render an opinion. Nevertheless it was in direct response to Galileo's request that Kepler wrote the "Conversation" during the week April 13–19.

26. The day in question was April 19, 1610. On that day Kepler finished writing the letter to Galileo containing his reaction to that great Italian scientist's telescopic discoveries (GW IV, 310:39; NE III, 125:29; X, 340:795). On that same day Giuliano de' Medici reported in a letter of his own to Galileo:

> I did not fail to turn over to Kepler the book you sent me. After he had examined it, he told me that he was highly pleased with it. . . . Kepler promises me to make some statements about your book at the earliest possible moment. As soon as I have them, I will send them to you (NE X, no. 296:8-10, 16-18; GW XVI, 303:2-4, 10-12).

The ambassador was as good as his word. He sent Kepler's statements (which later became the "Conversation") to Galileo by the couriers who left Prague for Tuscany on April 19, 1610. The document taken to Tuscany by the couriers is still preserved at the National Central Library in Florence.*

27. Sedesanus printed the "Conversation" at Kepler's expense (GW XVI, 355:31–32; NE X, 507:28).

28. In the Dedication of his "Message" Galileo called attention to his service as mathematics tutor of the Medici heir apparent (NE III, 56:33—57:1).

29. In 1609 Galileo's former pupil became the fourth Grand Duke of Tuscany, Cosimo II (1590–1621).

30. This date was mistakenly given as "Nonis Maji" (= May 7) by Frisch (F II, 449), whereas Kepler actually wrote "V. Nonas Majas" (=May 3; ed. 1610, fol. A2v; F II, 487; F VIII, 788; GW IV, 285:31).

31. This "Notice to the Reader" was translated into German by Max Caspar and Walther von Dyck, "Johannes Kepler in seinen Briefen" (Munich and Berlin, 1930), I, 342–344.

32. After hearing Galileo's request on April 13, Kepler hurriedly wrote the letter in a week to meet the deadline imposed by the departure of the couriers on April 19.

33. This "opponent" was Kepler's close friend, Wackher, who carried on an amicable running debate with Kepler about astronomical questions for a long time, as is made clear later, in Section I of the "Conversation," near Notes 44 and 55.

34. Kepler's "non nemo" (some) was improperly stretched to include "everybody" by Caspar-Von Dyck (I, 343: Jedermann), followed by Carola Baumgardt, "Johannes Kepler: Life and Letters" (New York: Philosophical Library, 1951), p. 82.

35. Opinions unfavorable to Galileo's book reached Prague from at least two Italian cities. From Venice, Georg Fugger reported to Kepler on April 16 that Galileo's book "to many experienced students of mathematics seems to be a dry discourse or a disguised deception without any scientific basis" (GW XVI, 302:12–13; NE X, 316, no. 292: 2–3). From Bologna it was related that on the night of April 25 many professors observed the heavens with Galileo's telescope in his presence, "but all declared that the instrument was deceptive, whereas Galileo kept quiet" (GW XVI, 308:92–93; NE X, 343:26–27). This test was conducted in the home of the professor of mathematics at Bologna who asserted, in a letter which was read in Prague on April 28, that "in my judgment Galileo's book and instrument are a fraud. . . . There are many others who oppose this opinion of Galileo, among them [a professor who] announced that he wanted to refute the whole book in public lectures" (NE X, 345:24–29). Koestler ("Sleepwalkers," p. 589; "Watershed," p. 268) professes to quote a passage translated into English from either or both of two Italian letters of April 15 and 28 (GW XVI, 300–301, 308). But neither in these GW excerpts nor in the complete letters (NE X, 314–315, 344–346) is there anything remotely resembling what Koestler pretends to be quoting from them.

36. "Commentary on Mars" is one of the short titles used by Kepler to designate the epoch-making work which he published in 1609 to announce his discovery that the orbit of Mars is an ellipse.

37. In the Dedication of his "Commentary on Mars" Kepler humorously treated that planet as though it were an enemy commander who, after an arduous campaign, was finally taken prisoner when his orbit was correctly determined.

38. In the opening paragraph of the "Conversation" Kepler compares himself, after the publication of his book on

Mars, to "a general who had won glory enough through a most strenuous military campaign." Kepler called attention to this resumption of the amusing martial metaphor of his book on Mars in order to justify his retention of the introduction against the wishes of the first critic of his "Conversation."

39. This contest between Kepler as loser and Wackher as victor forms a prominent part of Sections I and VIII of the "Conversation," near Notes 45, 55, 80, 318, and 382.

40. The catalogue of the Frankfurt book fair in the autumn of 1609 (*Catalogus universalis pro nundinis francofurtensibus autumnalibus de anno 1609,* fol. D1r) announced the publication of Kepler's book on Mars.

41. The title of Kepler's book on Mars proclaimed it to be a "New Astronomy . . . or Celestial Physics."

42. This correspondence began on August 4, 1597 (GW XIII, 130–131; NE X, 67–68), about twelve years before Kepler's book on Mars was published. In the letter of April 19, Kepler said "more than twelve years" (NE X, 320:8–9), but he deleted the expression "more than" from the published "Conversation" (ed. 1610, p. 1; GW IV, 288:16; NE III, 105:14). Galileo's letter of August 4, 1597, was received on September 1 by Kepler. Together with his answer of October 13, 1597, Kepler sent two additional copies of his "Cosmographic Mystery" in response to Galileo's request. At the same time Kepler urgently asked Galileo for his opinion of the book, to be expressed in a "very long letter" (GW XIII, no. 76:1, 8–9, 71–74). But no letter, long or short, was forthcoming from Galileo. Thus the correspondence between the two great scientists was interrupted for more than twelve years, from October 13, 1597, to April 19, 1610. Because Galileo declined to send Kepler his opinion of the "Cosmographic Mystery," did he in turn feel an understandable reluctance to ask Kepler directly for his opinion of the "Message"?

Was this an additional reason why Galileo sought the security of the diplomatic pouch to transmit a copy of his "Message" to Prague, and indirectly solicit Kepler's opinion of it through the Tuscan ambassador there?*

43. Bryk's mistranslation would mean: "I do not need to read any remote writings any more, but I can busy myself again with a completely unfamiliar question."

44. Wackher was born of a poor family at Constance in 1550. After winning a law degree, he spent the following years in travel as the private tutor of a wealthy Wrocław youth. Then he was appointed to an administrative post in the government of Silesia. With an eye to his advancement in the bureaucracy, he accepted conversion to Roman Catholicism in 1592, and two years later he was rewarded by being elevated to the nobility with the title "of Wackenfels" (not "Wackenfeld," despite Koestler, "Sleepwalkers," p. 370; "Watershed," p. 192). After moving to Prague, then the capital of the Holy Roman Empire, Wackher became a member of the Imperial Aulic Council. Having accumulated a considerable fortune, he died on September 7, 1619, at the ripe old age of sixty-nine. His biographer [Theodor Lindner, Z. *ver. Geschichte und Alterthum Schlesiens* **8,** 319–351 (1867)] relied mainly on unpublished correspondence; had he not overlooked Kepler's remarks about Wackher's scientific interest and outlook, he would not have made the mistake (pp. 333–334) of aligning Wackher with the Aristotelians.*

The second part of Wackher's title was not included by Kepler in the letter of April 19 (NE X, 320:13), but he inserted it in the published "Conversation" (ed. 1610, p. 1:6–5 up; GW IV, 288:21–22; NE III, 109:20). Wackher was elevated to the position of Referendary (Master of Petitions) on April 16, 1607 (Felix Stieve, "Die Politik Baierns," Munich, 1878–1883, II = "Briefe und Acten zur Geschichte des dreissigjährigen Krieges," V, 820, n. 3). The history of the Imperial Aulic Council as a judicial and political body was discussed briefly by Henry Frederick Schwarz, "The Imperial Privy Council in the Seventeenth Century," Harvard Historical Studies, LIII (Cambridge, Mass., 1943), pp. 16–19.

45. In the letter of April 19, the reactions of Kepler and Wackher to the news of Galileo's discovery were narrated more compactly: "Intense astonishment seized both of us. As we weighed this very strange pronouncement, our emotions were so strongly aroused that, overcome with joyful laughter, he did not manage to talk nor I to listen" (NE X, 320:14–16). The expanded version in the published "Conversation" is valuable for its reference to the previous disagreement between Kepler and Wackher (ed. 1610, p. 1:2–1 up; GW IV, 288:25; NE III, 105:23).

46. Bryk's mistranslation ("whether the number of the planets could not somehow be established") misses the reason for Kepler's shame and fear that his published work would be harmed by Galileo's discovery. Kepler's previous contention that there could be only six planets would of course be demolished by "any increase in the number of planets" (aliqua . . . accessio ad planetarum numerum).

47. Since the title page of the "Cosmographic Mystery" is dated 1596, this statement may seem imprecise. However, the book was printed toward the end of the year 1596, and Kepler's acknowledgment of the receipt of the first copy is dated December 28, 1596 (old style) = January 7, 1597 (new style; GW XIII, no. 56:1, 34). In the letter of April 19 Kepler's alternative formulation was unobjectionable. There he told Galileo that his "Cosmographic Mystery" "has been available to the public for thirteen years" (NE X, 320:24). The book was in fact announced in the catalogue of the Frankfurt book fair in the spring of 1597 (*Catalogus novus nundinarum vernalium, Francofurti ad Moenum, anno MDXCVII celebratarum;* for Tobias Lutz: Appendix, fol. D3r; for Paul Brachfeld: fol. Blv).

48. The five regular solids (pyramid, cube, octahedron, dodecahedron, icosahedron) form the subject matter of Book XIII of Euclid's "Elements," which was written about 300 B.C. The English translation by Thomas L. Heath, "The Thirteen Books of Euclid's Elements" (2nd ed., Cambridge Univ. Press, 1926) was reissued in 1956 by Dover, New York.

49. Proclus (†485 A.D.), "Commentary on Book I of Euclid's Elements" (ed. Friedlein, Leipzig, 1873, 65:20, 70:24, 71:23–24, 423:13–14). The passage in Proclus which in all probability prompted Kepler's remark was translated into English by Ivor Thomas, "Greek Mathematics," 2nd ed. (Loeb Classical Library, 1951), I, 149. This passage was available to Kepler in the first printed edition of the Greek text of Euclid's "Elements" (Basel, 1533; p. 19 of the separately paginated Proclus section). According to Proclus, "the construction of the cosmic figures was discovered" by Pythagoras. Even if they were first put together by Pythagoras in the sixth century B.C., there is no reason to believe that he called them "cosmic." Nor did Plato (427–347 B.C.) so label them, although he built his cosmos out of them ("Timaeus," 53C–56C). Hence we must reject Kepler's notion about the nomenclature used by Pythagoras and Plato. In the letter of April 19, Kepler said that Proclus followed Pythagoras' and Plato's statement (sententia; NE X, 320:25). But neither in the letter nor in the published "Conversation" did Kepler say that Proclus followed Pythagoras' and Plato's world-view (despite Bryk, p. 324: Weltansicht). In his "Harmonics of the Universe" (1619; GW VI, 80:12–13) Kepler still clung to the idea that Plato applied the term "cosmic" to the five regular solids, but there he prudently substituted the "Pythagoreans" for Pythagoras, as he did also in his "Epitome of Copernican Astronomy" (1620; GW VII, 267:23–25).

50. Even more explicit than the "Cosmographic Mystery" was Kepler's characteristic reasoning about this topic in a

letter dated October 3, 1595: "The world of motion must be considered as made up of rectilinear [regular solids]. Of these, however, there are five. Hence if they are to be regarded as the boundaries or the partitions . . . they can separate no more than six objects. Therefore six movable bodies revolve around the sun. Here is the reason for the number of the planets" (GW XIII, 35:74–78).

51. "I interposed a new planet between Jupiter and Mars, and also another one between Venus and Mercury, both being invisible perhaps on account of their small size, and I assigned them their periods of revolution" (GW I, 10: 19–21).

52. Near the end of the Preface Kepler confessed to the reader that in the "Cosmographic Mystery" "you will not find the new and unknown planets which I interposed a little while ago" (GW I, 14:12–13). A quarter of a century later, in the second edition (Frankfurt, 1621) of the "Cosmographic Mystery," Kepler made a characteristically forthright statement about the planet which he had imagined in the vicinity of Jupiter: "It was not to revolve around Jupiter, like Galileo's Medicean bodies. Make no mistake, I never thought of them. Instead, like the primary planets, it was to run its course around the sun, located at the center of the system" (F I, 110: note e).

53. Kepler's "curriculo" (promptly) was misunderstood by Bryk to mean "by letter" (brieflich, p. 324). Kepler and Galileo would have had to exchange views by letter ("per literas") since they lived far apart, but Kepler and Wackher both lived in Prague.

54. Nicholas Copernicus (1473–1543) quoted with approval from an ancient writer the opinion that "the earth . . . is one of the celestial bodies" ["Revolutions," I, 5; Franz Zeller and Karl Zeller, eds., Nikolaus Kopernikus "Gesamtausgabe," II (Munich and Berlin: Oldenbourg, 1949), 15:4–5; English translation in "Great Books of the

Western World" (Chicago: Encyclopaedia Britannica, 1952), XVI, 515].

55. Wackher's contention that the newly discovered bodies would turn out to be planets revolving around stars was not mentioned by Kepler in the letter of April 19 (NE X, 320:36), but was inserted in the published "Conversation."

56. This reference to Nicholas of Cusa (1401–1464) is likewise absent from the letter of April 19, and present in the published "Conversation." Actually Cusa did not speculate about planets encircling fixed stars. In the "Conversation" Kepler's formulation is such that it may appear to be Wackher, rather than Kepler, who is citing Cusa incorrectly. Yet a few months later, on September 11, 1610, in his "Report on His Observations of Jupiter's Four Satellites" entirely on his own account Kepler published the following rhetorical question about Galileo's "Message": "If its author intended to lie about new planets, why, may I ask, did he not invent infinite planets around infinite fixed stars, to agree . . . with the Cardinal of Cusa?" (GW IV, 317:24–27; NE III, 183:21–23).

Although Kepler saluted Cusa as "godlike" (GW I, 23: 13–14), he was not well acquainted with the cardinal's writings. It has even been suggested that he knew Cusa's cosmological views only by hearsay [Dietrich Mahnke, "Unendliche Sphäre und Allmittelpunkt" (Halle, 1937) = *Deut. Vierteljahrsschr. Literaturwiss. und Geistesgeschichte* **23,** 130]. If so, Wackher may well have been the source of Kepler's misinformation about Cusa. In any case there is little, if any, foundation for Pierre Duhem's confident assertion that "Kepler surely knew the various treatises of Nicholas of Cusa" ["Etudes sur Léonard de Vinci" (Paris, 1906–1913; reissued, Paris: De Nobele, 1955), II, 202].

57. This reference to Giordano Bruno (1548–1600) was absent from the letter of April 19 (NE X, 320:36) and was inserted in the published "Conversation" (ed. 1610,

p. 2:7 up). In his "De innumerabilibus, immenso, et infigurabili" (Frankfurt, 1591) Bruno referred to "the planets which are around the other suns," and to the "planets revolving around other fixed stars, that is, suns" ("Opera latine conscripta," Naples and Florence, 1879–1891; facsimile reprint, Friedrich Frommann Verlag Günther Holzboog, Stuttgart-Bad Cannstatt, 1962; I, Part 1, pp. 209, 213). This concept of planets revolving around stars was mistakenly attributed also to Cusa by Kepler, as we saw earlier in Note 56.

58. This alternative vanishes in Bryk's mistranslation (p. 324).

59. About the middle of the fifth century B.C. the Greek philosopher Melissus "maintained that the universe is infinite . . . and unique" (Diogenes Laertius, "Lives and Opinions of the Philosophers," IX, 24). Although other ancient writers who discussed Melissus' lost treatise may have been known to Kepler, he probably relied on Diogenes Laertius in this instance, as he frequently did with regard to other ancient thinkers throughout his long career as an author. Thus as early as his "Defence of Tycho" (F I, 249, 250) and as late as his notes on his translation of Plutarch's "Face in the Moon" (F VIII, 116), and often in between (GW II, 198:30, 265:25; III, 409:3; XV, 209:15, 218:488–489; F I, 160; VI, 105; VIII, 42, 280), Kepler cited Diogenes Laertius, who was available in many editions, both in the original Greek and in Latin translation. The infinity and unicity of the universe form integral parts of Melissus' thought, as reconstructed by J. H. M. M. Loenen, "Parmenides, Melissus, Gorgias" (New York: Humanities Press, 1961), p. 144.

60. William Gilbert (1544–1603) was greatly admired and highly praised by Kepler, who was deeply and beneficially influenced by the English scientist's "De magnete" (London, 1600). But both Wackher and Kepler went too far in ascribing to Gilbert the view that the universe is infinite.

Actually Gilbert believed (VI, 3; ed. 1600, p. 220) that "the universe's . . . bounds are unknown and unknowable." This idea, and even the very words in which it was expressed, were taken by Gilbert from Copernicus' "Revolutions" (I, 8; ed. Zeller, II, 19:11; "Great Books," XVI, 519). But Copernicus stopped short of declaring the universe to be infinite. Describing it as an "immense sphere, similar to the infinite," he left the question "whether the universe is finite or infinite to the discussion of the natural philosophers" (ed. Zeller, II, 19:7–8; 31:9–8 up; see Rosen, "Three Copernican Treatises," pp. 39–40). In his "New Star" (1606; GW I, 253:4–8) Kepler had been careful to avoid making the categorical statement that Gilbert believed the universe to be infinite. But that caution vanished when (under Wackher's influence?) here in the "Conversation" Kepler linked Gilbert with Melissus. In his "Epitome of Copernican Astronomy" (1618; GW VII, 81:16–19; 578) Kepler again unwarrantedly expanded Gilbert's universe to infinity. There are two English translations of Gilbert's "De magnete." The earlier one, by Paul Fleury Mottelay (New York and London, 1893) has been reprinted twice: in "Great Books," XXVIII, and also by Dover, 1958. The other translation, by the Gilbert Club (London, 1900), was reprinted by Basic Books, 1958.

61. In the second half of the fifth century B.C. the Greek philosopher Democritus believed that "there are innumerable worlds," according to Diogenes Laertius (IX, 44), who was probably Kepler's principal source of information about Democritus.

62. The Greek philosopher Leucippus, who originated the atomic theory about the middle of the fifth century B.C., held that "there are innumerable . . . worlds," according to Diogenes Laertius (IX, 31), who was probably Kepler's source for Leucippus.

63. "There is a single universal space, a single immense place, which we may freely call 'the void.' In it there are

innumerable and countless globes, like this one on which we live and develop. I call this space infinite. . . . In it there are countless worlds like this one and of a kind not different from this one" [Bruno, "Dialoghi italiani," 3rd ed., ed. Giovanni Aquilecchia, Florence: Sansoni, 1958, p. 518; English translation in Dorothea Waley Singer, "Giordano Bruno" (New York: Abelard-Schuman, 1950), pp. 58–59, 363]. Kepler confessed to Galileo: "I am a beginner in Italian" (GW XVI, 341:6). Hence, if Kepler shows a familiarity with ideas expressed in the Italian writings, as distinguished from the Latin works, of Bruno, his informant may well have been Wackher.

64. Edmund Bruce was an Englishman about whom little is known beyond the fact that he lived in Italy during the early years of the seventeenth century.

65. Actually Bruce was not a close friend of Galileo. He was not even friendly to Galileo, since he transmitted to Kepler, as unquestioned statements of fact, base and baseless gossip which was very harmful to Galileo's professional reputation. Bruce talked to Galileo about Kepler, as he reported in a letter sent to Kepler from Florence on August 15, 1602: "Galileo told me that he had written to you, and that he had received your book" (GW XIV, 256:11–12; cf. 441:19; NE X, 90:9; 104: no. 94). The book in question was Kepler's "Cosmographic Mystery," the receipt of which Galileo acknowledged in his letter to Kepler of August 4, 1597, which was cited earlier in Note 42.

66. Whether Kepler and Bruce ever met face to face is not known, nor is it known how their correspondence began. But on July 18, 1599, Kepler sent Bruce a very long letter which it took him the whole day to compose (GW XIV, 16:351; NE X, no. 66). Bruce wrote to Kepler from Padua (GW XIV, 256:1–2; NE X, no. 81:1), from Florence on August 15, 1602, and again from Padua on August 21, 1603 (GW XIV, no. 222, 265; NE X, 104, no. 94). Of these three letters, only the last two reached Kepler, who

answered on September 4, 1603. In this letter Kepler asked Bruce to transmit his greetings to Galileo (GW XIV, 445:33). Bruce replied to Kepler from Venice on November 5, 1603 (GW XIV, no. 272).

67. In his letter of November 5, 1603, Bruce told Kepler: "I am of the opinion that there are countless worlds. But each world is just as finite as is that of the planets in whose center is the center of the sun" (GW XIV, no. 272: ll. 11–12). At the time Kepler received this letter, he paid scant attention to it after he came to Bruce's remark that "in astronomy I have many doubts which you alone may clear up for me" (ll. 9–10). But, many years later, having heard the news about Galileo's discovery of previously unknown celestial bodies, on April 5, 1610, Kepler bethought himself of Bruce's letter and jotted down his delayed reactions to it (ll. 39–51).

68. This parenthesis was not included in the letter of April 19 (NE X, 321:40), but was inserted in the published "Conversation," perhaps with reference to Bruno's statement in his "De l'infinito": "I say that there are countless earths" ("Dialoghi," p. 411; Singer, "Bruno," p. 283). Paul-Henri Michel, "La cosmologie de Giordano Bruno" (Paris: Hermann, 1962) analyzes this aspect of Bruno's writings acutely and sympathetically. Although Bruno himself was no scientist, his poems and dialogues contained ideas which contributed mightily to our understanding of the universe through their influence on Kepler and others.

69. This similarity had been stressed by Kepler in his "New Star": "Bruno makes the universe infinite in such a way that there are as many worlds as there are fixed stars, and this region of our movable [bodies] he makes one of the innumerable worlds, differing in scarcely any characteristic from the other worlds situated around it. Therefore if anybody were on the Dog Star . . . to him observing from up there, the universe would look the same as it appears to us from here as we gaze upon the fixed stars from our world"

(GW I, 253:8–14). By contrast, in Democritus' cosmology the countless other worlds were different from ours: "There are innumerable worlds, and they differ in size. In some there is neither sun nor moon, while in others these are larger than ours, and in still others, more numerous. The distances of the worlds are unequal, and in one region there are more, in another fewer. Some are expanding, others are at their maximum, and still others are disintegrating. In one region worlds are born, in another they pass away. They are destroyed by colliding with one another. Some are devoid of animals, plants, and all moisture" (Geoffrey S. Kirk and John E. Raven, "The Presocratic Philosophers," Cambridge Univ. Press, 1957, p. 411).

70. This reference to Wackher's opinion was unjustifiably omitted from Bryk's translation (p. 324).

71. The impatience of Kepler and Wackher was expressed even more forcibly in the letter of April 19 (NE X, 321: 42) by the inclusion of "on pins and needles" (discruciati, which was omitted from the published "Conversation").

72. Not "one of the first" (despite Bryk, p. 325). Kepler evidently means the first copy to reach Prague.

73. Rudolph II (1552–1612), emperor of the Holy Roman Empire.

74. The words in quotation marks paraphrase a part of the title of Galileo's "Message."

75. The words "including myself" were omitted by Bryk (p. 325), who failed to recognize that Frisch (F II, 490: 21) had printed "including myself, if I am not mistaken" as though that expression formed part of Kepler's paraphrase of Galileo's title.

76. The words in quotation marks are quoted from Galileo's "Message" (NE III, 62:16–17; Carlos, p. 14; Drake, p. 31).

77. In 1604 Kepler published a work which, like Galileo's "Message," treated both optics and astronomy. In fact, the last six of its eleven chapters carry as their running head "Optical Part of Astronomy." The running head over the first five chapters repeats the opening words of the title: "Additions to Witelo," who was the foremost medieval writer on optics in the West. In referring to this work, Kepler sometimes calls it his "Additions to Witelo," at other times his "Optical Part of Astronomy," and at still other times simply his "Optics." This last designation, being the briefest, will be adopted here.

78. "He" (Jehovah) was replaced by "you" (Galileo) in Bryk's translation (p. 325).

79. In the letter of April 19, Kepler had said: "through mouth, tongue, and pen" (NE X, 321:51).

80. In the published "Conversation" Kepler said "invisum," replacing "inrisum" in the letter of April 19 (NE X, 321: 55). According to the earlier version, Wackher ridiculed Kepler; according to the later version, Wackher was angry at Kepler. But neither version means "entirely against my disposition," despite Bryk (p. 325).

81. Kepler's "plane conclusum" (it was definitely concluded) implies agreement on the part of both Kepler and Wackher, not Wackher alone (as Bryk thought, p. 325).

82. This letter from Galileo to Giuliano de' Medici has not survived, as we saw earlier in Note 25.

83. Galileo's "Message."

84. Kepler's "ostendendam" did not go so far as to suggest "publication," despite Bryk (p. 325). In a letter dated May 7, 1610, Galileo mentioned that he had received Kepler's private letter of April 19 (NE X, 349:18–22; GW XVI, no. 572:1–5; see Note 283, below). Then in a letter to Kepler of August 19, 1610, Galileo acknowledged receipt of the "Conversation" in its printed form, and ex-

pressed the intention of replying to it in a second edition of his "Message" (NE X, 421:2–4; GW XVI, 327:2–4). But no second edition of Galileo's "Message" was ever published, nor was any reply by Galileo to Kepler's "Conversation" ever published. Yet in his private letter of August 19, 1610, to Kepler, Galileo both acknowledged receipt of Kepler's "Conversation" and expressed his gratitude for it, despite Koestler's statement that Galileo "neither thanked Kepler nor even acknowledged it" ("Sleepwalkers," p. 371; "Watershed," p. 193). As early as May 24, 1610, Galileo wrote to a doctor in Paris that Kepler's "Conversation" "is now being reprinted in Venice" (NE X, 358:27; GW XVI, no. 574:7–8). Galileo applied for the appropriate license [*Riv. biblioteche* **2**, 102 (1889)], which was granted by the Venetian authorities on July 6, 1610 (NE XIX, 229:10). Nevertheless the Venetian edition never actually materialized, perhaps because Galileo was forestalled by the pirated Florence edition of 1610 (see the Introduction at Note 10).

85. After four months Kepler was very nearly the only partisan of Galileo, as the latter informed Kepler in the letter of August 19, 1610, which was cited earlier in Note 84: "I thank you because you were the first one, and practically the only one . . . to have complete faith in my assertions" (NE X, 421:4–6; GW XVI, 327:4–6).*

86. Kepler's confident characterization of Galileo as a man who does not pretend "to have seen what he has not seen" vanishes in Bryk's faulty rendering (pp. 325–326).

87. The letter of April 19 (NE X, 321:72) and the edition of 1610 (p. 4:13) agree in reading "Quid quod." This unobjectionable wording was unnecessarily emended to "Qui quod" by Frisch (F II, 491:1), who was followed by GW IV, 290:19.

88. Kepler was troubled by multiple vision or polyopia, as he explained in the "Optics": "Instead of a single small

object at a great distance, two or three are seen by those who suffer from this defect. Hence instead of a single moon, ten or more present themselves to me" (GW II, 180:36–38; in his book on "Comets," Kepler said "six, eight, or ten," F VII, 82). However, Kepler's multiple vision was caused only by strong light. Thus in the "Optics" he said: "People who have weak eyes and who at other times see badly at a distance picture to themselves a tufted series of ten phases instead of a single phase [of the moon]. When they look at men wearing white collars at a distance, they do not identify the men's faces, which are quite recognizable apart from this circumstance. . . . When eclipses of the moon begin, I, who suffer from this defect, become aware of the eclipse before all the other observers. Long before the eclipse starts, I even detect the direction from which the shadow is approaching, while the others, who have very acute vision, are still in doubt. . . . The aforementioned waviness of the moon stops for me when the moon approaches the shadow, and the strongest part of the sun's rays is cut off" (GW II, 194:33—195:5). Similarly, in a letter to a correspondent on August 31, 1619, Kepler said with regard to a lunar eclipse: "Where the moon is bright, it spreads itself out in my vision by being multiplied into many circles intertwined with one another so as to look like a bigger sphere; but where the moon is dim, there that multiplication stops" (GW XVII, 377:70–72). Besides being bothered by multiple vision, Kepler was also nearsighted. In his "Optics" he discusses the case of a man who "reads very tiny letters, but he brings them so close to his eyes that he can't use both eyes at the same time. His clear vision does not extend as far as ten paces, where he sees nothing but clouds. Yet he is helped by strongly concave lenses to see at a distance. These lenses make my vision completely confused, although I myself use concave lenses of a more moderate curvature" (GW II, 182:9–14).

89. On the title page of his "Message" Galileo announced, with reference to the four satellites of Jupiter which he

had just discovered, that "he decided they should be called the Medicean bodies" (NE III, 53; Carlos, p. xvi; Drake, p. 21).

90. "Of all mirrors, the full moon is the best and clearest in smoothness and brightness" (Plutarch, "The Face in the Moon," 921A). Was this passage brought to the attention of Rudolph II by Kepler, the Imperial Mathematician, who cited Plutarch's "Moon" very often in his "Optics"? If so, the emperor's interpretation of moonspots as reflections of terrestrial land masses modified Plutarch's view that "there are mirror images and reflections of the big ocean appearing in the moon as the so-called face" (920F).

91. Presumably Corsica and Sardinia.

92. Kepler's "vocabulo" was misequated by Bryk (p. 326) with "merely verbal disputes," which Galileo early in 1610 "learned" to subordinate to contemplation of the heavens. But "vocabulo" does not imply "disputes," an idea interpolated by Bryk, as is also the idea that Galileo first "learned" in 1610 to subordinate "merely verbal disputes." Actually Kepler's Latin says nothing about disputes and nothing about learning. By "vocabulo" he means the "appellation" of a Christian, that is, a follower of Jesus of Galilee, or a Galilean. The implied pun on Galileo's name became explicit in a poem by Seget which was appended to Kepler's "Report on His Observations of the Four Satellites of Jupiter" (GW IV, 324:14; NE III, 189:19; X, 455). There Seget exclaimed "You have conquered, O Galileo," in a punning recollection of the exclamation "You have conquered, O Galilean," which an unhistorical Christian legend invented as the dying words of an anti-Christian Roman emperor [Giuseppe Ricciotti, "Julian the Apostate" (Milwaukee: Bruce, 1960), p. 254]. This pun appealed not only to the admirers of Galileo, but also to his bitterest enemies. Preaching a sermon on December 21, 1614, in Florence, where Galileo was then living, a Dominican condemned the activities of Galileo and all other

astronomers. According to a much later source, the Dominican repeated the question in Acts 1:11: "Ye men of Galilee, why stand ye gazing up into heaven?" [Angelo Fabroni, ed., "Lettere inedite di uomini illustri" (Florence, 1773–1775), I, 47].

93. Galileo vied with the emperor, since the latter was observing the moon while Galileo was watching Jupiter's satellites. Kepler does not say that Galileo "could appreciate the happiness" of the emperor, despite Bryk (p. 326).*

94. Kepler's reference to Pythagoras in this connection was a slip, since no statement regarding moonspots was attributed to Pythagoras (or the Pythagoreans). But immediately after a remark about the Pythagoreans' conception of the moon, Pseudo-Plutarch's "Opinions of the Philosophers," II, 30, attributed to Anaxagoras the belief that in the moon "mixed with the fiery matter is the darkish matter." This passage had long been familiar to Kepler (see Notes 234–235, below), but in 1610 he may have failed to recall the transition therein from the Pythagoreans to Anaxagoras. Democritus was credited with the assertion that the moon shows "a shadow from the high places on it, since it has valleys and ravines" (Joannes Stobaeus, I, 26, 4; ed. Berlin, 1958, I, 222:17–18). But did Kepler have a firsthand acquaintance with Stobaeus (ed. Antwerp, 1575)?

95. Plutarch (ca. 50–ca. 120 A.D.) in the "Moon" said: "The moon's diameter at its mean distance measures twelve digits in apparent size. Each of the black and shadowy spots seems bigger than half a digit, so that it is greater than one twenty-fourth of the diameter. Now if we assume the moon's circumference to be only 30,000 stades, and the diameter 10,000, according to the hypothesis each of the shadowy spots on it would be no less than 500 stades" (935 D–E). Plutarch's "Moon," the most important ancient discussion of that body, was translated from Greek into Latin by Kepler. His translation accompanied his

own "Dream or Posthumous Work on Lunar Astronomy" (Zagan and Frankfurt, 1634, pp. 97–184) and was reprinted by Frisch (F VIII, 76–123). An English translation by Harold Cherniss was published in 1957 in the Loeb Classical Library, Plutarch's "Moralia," XII, 35–223.

96. Plutarch was mentioned twice as an eminent philosopher by Eusebius of Caesarea in his "Chronicle," which was written about 325 A.D. (Alfred Schoene, ed., Berlin, 1866–1875, II, 156, 164). Although the original Greek text of Eusebius' "Chronicle" has not survived intact, a Latin translation which was done about 380 by Jerome was published by Joseph Justus Scaliger (1540–1609) in his "Thesaurus temporum" (Leiden, 1606). This complex volume was studied avidly by Kepler, who was intensely interested in such current controversies as were provoked by the recently introduced Gregorian calendar and the hotly debated question concerning the year in which Jesus was born. In Scaliger's "Thesaurus" Kepler may have noticed Eusebius-Jerome's references (pp. 162, 166) to Plutarch as an eminent philosopher.

97. Plutarch "in his old age was appointed by the emperor to govern Greece." This statement was printed for the first time in Scaliger's "Thesaurus," in the section which he labeled the surviving Greek fragments of Eusebius (p. 81:32–33). But Kepler refers to Epirus, not to Greece, and he specifically assigns to Plutarch "the power of a proconsul." Now according to another Greek work, Plutarch "lived at the time when Trajan was the Caesar, and before that. Trajan gave him the rank of a consul, and ordered that none of those who governed in Illyria should do anything without his approval" [Suidas, Ada Adler, ed. (Leipzig, 1928–1938), IV, 150:26–29]. This Byzantine lexicon, which was compiled about 1000 A.D., and was available to Kepler in three printed editions, was cited by Scaliger in his comments (pp. 195 [misnumbered 197] and 211) on the two Plutarch passages in Eusebius-

Jerome. Did Kepler base his statement about Plutarch's administrative activity on a combination of the Greek "Eusebius" with Suidas? Did Kepler say that Plutarch exercised this authority "under the Caesars" because, according to Suidas, he received it from Trajan, but from Trajan's successor Hadrian, according to the Greek "Eusebius"? If so, "Eusebius'" statements about Plutarch need further examination. For, Hadrian's appointment of Plutarch is found neither in Jerome's translation of Eusebius [Rudolph Helm, ed., *Die griechischen christlichen Schriftsteller der ersten Jahrhunderte* **47** = Eusebius VII (Berlin, 1956), pp. 185:1–2, 198:1–3] nor in the Armenian translation of Eusebius [Joseph Karst, ed., *Die gr. ch. Schriftsteller* **20** = Eusebius V (Leipzig, 1911), pp. 216, 219]. Hence Hadrian's appointment of Plutarch may not have been present in the original Greek text of Eusebius, despite Scaliger. He found Hadrian's appointment of Plutarch in the "Chronography" which was written about 800 A.D. by the Byzantine compiler George Syncellus [ed. Dindorf, *Corpus scriptorum historiae byzantinae,* **12–13,** (Bonn, 1829), I, 659:13–14]. The assertions by Syncellus and Suidas about Plutarch's place in the governmental machinery of the Roman Empire are regarded with skepticism by modern scholars, some of whom are nevertheless inclined to believe that within these coarse husks preserved in Syncellus and Suidas a kernel of truth may be hidden.

98. Michael Mästlin (1550–1631) taught astronomy to Kepler at Tübingen University.

99. In Section V, at Notes 182 and 254.

100. Kepler's "longe" was mistranslated as "for a long time now" by Bryk (p. 327). But Galileo's observations had been in print only a month.

101. The newly discovered bodies were so designated for the first time in print by Kepler in his "Report on His Observations of the Four Satellites of Jupiter," which is dated

September 11, 1610 (GW IV, 322:38–39; NE III, 188:5–6). At the cost of a slight anachronism of a few months, then, the term "satellite" may be imported into the "Conversation" in place of what Kepler actually wrote: "circum-Jovial planets" and the like.

102. Again at the cost of anticipating by nearly a year, we may import the term "telescope" into the "Conversation," although it was actually used in public for the first time on April 14, 1611 (Rosen, "The Naming of the Telescope," p. 67).

103. Kepler's "sex vel octo" (six or eight) does not mean "from six to eight," despite Bryk (p. 327), followed by Caspar, "Kepler," p. 225 (Caspar-Hellman, p. 195), nor does it mean "five or eight," despite J. B. J. Delambre, "Histoire de l'astronomie moderne" (Paris, 1821), I, 470. Those who committed these errors overlooked the fact that Kepler was thinking of a mathematical progression. Since four satellites had been discovered by Galileo around Jupiter, the second of the three outermost or superior planets, then Mars below it (Kepler reasoned) must have two satellites, and Saturn above it must have either six or eight satellites, depending on whether the progression was arithmetical (2–4–6) or geometrical (2–4–8). The only doubt in Kepler's mind was whether the progression was arithmetical or geometrical. But he did not have the slightest doubt that there must be a progression. To complete his neat little design, Kepler was ready to donate one satellite each to Venus and Mercury, the two innermost or inferior planets, so that they would resemble the planet earth accompanied by the moon (1–1–1–2–4–6 or 8).

Subsequent telescopic discoveries have revealed no such simple arrangement as Kepler envisaged. Mercury and Venus in fact have no satellites. Mars does indeed have two. To Galileo's four satellites of Jupiter, eight others have since been added by later observers. Saturn has nine satellites, to say nothing about the swarm of particles constituting its three rings. Moreover, the solar system has expanded outward to include Uranus with its four satellites, Neptune with its two satellites, and Pluto. Moreover, the host of planetoids (or minor planets or asteroids) moves the actual pattern even further away from Kepler's pretty picture [Patrick Moore, "The Planets" (New York: Norton, 1962)].

104. In the letter of April 19, Kepler forgot to say that this satellite would revolve around Venus (NE X, 322:100).

105. Kepler does not say "3° or somewhat more," despite Bryk (p. 327), who interpolates into Kepler's text the remark that the error should be neglected, whereas Kepler called particular attention to it. In his "Cosmographic Mystery" Kepler had evaluated the planetary tables in current use as follows: "Between the true position and that predicted by computation there is frequently a great discrepancy, which sometimes in certain cases amounts to two full degrees in longitude" (GW I, 60:21–23). However, after acquiring a greater knowledge of practical astronomy, in the second edition of the "Cosmographic Mystery," Kepler inserted the following note on the passage quoted above: "For Mars . . . the *Prussian Tables* are in error, at certain places in the orbit, by 3°" (F I, 168:b).

106. $A \cong 1000\,a$, if $D^2 = (32\,d)^2 = 1024\,d^2$.

107. "Since nature has given every living creature two eyes, at some distance from each other, the sense of sight uses this aid quite correctly to judge the distances of visible objects, so long as those distances bear a perceptible ratio to the distance between the eyes. . . . In vision, common sense is familiar with the distance between the eyes, but by feeling that the eyes are turning, it takes note of the angles associated with the distance of the object. For when the object is so far away that in comparison with its distance, the distance between the two eyes vanishes, the axes

of the eyes become almost parallel. On the other hand, the nearer the object, the more the two eyes turn toward each other" [Kepler, "Optics"; GW II, 66:22–25, 30–35; cf. 268:20—269:12; see Vasco Ronchi, "Optics, the Science of Vision," Edward Rosen, trans. (New York Univ. Press, 1957), pp. 43–44].

108. Kepler says "Belgians." But for him, as for his contemporaries, "Belgians," "Hollanders," and "Batavians" were interchangeable terms. Thus, as we shall see later on, at Note 323 in Section VIII, in the "Conversation" Kepler referred to a famous Arctic voyage "of the Belgians" (GW IV, 304:20), which he had previously ascribed to Hollanders and Batavians in the "Optics" (GW II, 128:1–2).

109. The first edition (Naples, 1558) of this immensely influential work was published by Della Porta in only four books. Thirty-one years later he expanded it to twenty books (Naples, 1589). The Frankfurt, 1597 edition of the enlarged version was studied by Kepler intensively and critically (GW XIV, no. 242:136–140, 207–210). The numerous editions and translations of Della Porta's "Natural Magic," as well as his curiously inconsistent statements about his own career, were discussed by Edward Rosen, "The Naming of the Telescope," pp. 6–30. The anonymous English translation of Della Porta's "Natural Magic" (London, 1658) has been reissued by Basic Books (New York, 1957).

110. In his letter of April 19 (NE X, 323:124) and also in the 1610 edition of the "Conversation" (p. 6:12 up) Kepler mistakenly wrote "affectibus," which was printed also by Frisch (F II, 492:6). Bryk (p. 328) was misled by Kepler's error into translating the title of Della Porta's chapter as "The Diseases of the Crystalline Lens" of the eye. But the word actually used by Della Porta was "effectibus," and his chapter dealt with the effects produced by an optical lens made out of rock crystal. There are other

places where Della Porta's language is not faithfully reproduced by Kepler, but these departures do not significantly alter Della Porta's meaning.

111. Kepler's "et" does not mean "or," despite Bryk (p. 328). Kepler quoted this long passage from Della Porta precisely because as early as 1589 it recommended the combination of a concave *with* a convex lens.

112. Della Porta's "ex una in alteram" means "by one [lens] after another," not "one written character after another," despite Bryk (p. 328). Della Porta is thinking of a series of increasing magnifications produced by an array of lenses focused on the same written character. He is not thinking of magnifying one written character after another. The material in italics was emphasized by Kepler, not by Della Porta.

113. Not Chapter 1, despite Bryk (p. 328).

114. Kepler's "Over Chapter 11 he sets a new heading" was mistranslated by Bryk (p. 328) as "In Chapter 11 he makes a big fuss."

115. Della Porta's "specillis" (lenses) was mistranslated by Bryk (p. 328) as "telescopes." This misunderstanding led Bryk to speak (p. xiii) of Della Porta's "invention of the telescope," and (p. xxxvi) of "Della Porta's claims" in the "Natural Magic" to have invented the telescope. Actually, Della Porta neither invented the telescope nor claimed to have done so until Galileo published the "Message," and Kepler the "Conversation" (Rosen, "The Naming of the Telescope," pp. 6, 16–20).

116. In the letter of April 19 (NE X, 323:142) Kepler said "only with transparent lenses." By omitting "only" (solis) from the published version of the "Conversation," Kepler slightly softened his adverse judgment of Della Porta's discussion.

117. Not Chapter 1, despite Bryk's repetition of this error (p. 329).

118. Della Porta's "specillorum" (glasses) was confused with "mirrors" (speculorum) by Bryk (p. 329).

119. Bryk (p. 329) failed to recognize "Optical Part of Astronomy" as one of the short titles by which Kepler referred to his "Optics." Bryk apparently suffered from the delusion that Kepler had written an "Astronomy" containing a section on light.

120. Not "telescopes," despite Bryk (p. 329). In his "Optics" Kepler said nothing about telescopes, because he had not yet heard about them.

121. Of the 1604 edition (GW II, 182).

122. Although Kepler's drawings of a concave and convex lens are combined, in 1604 he had no idea of actually uniting a concave and convex lens in a single optical system. His diagram illustrating the refraction produced by a biconcave lens happens to be placed directly above his diagram illustrating the refraction produced by a biconvex lens. But these independent refractions form two separate optical systems, with the light entering them from opposite directions and impinging on the eye situated between them. The rays emerging from the upper or biconcave system do not continue on into the lower or biconvex system, whereas "in the familiar tubes" the two lenses constitute a unified optical system.*

123. Kepler was mistaken in assuming that Della Porta was already dead. Actually the hardy Neapolitan lived until February 4, 1615 [*Mem. reale accad. naz. Lincei, Classe sci. morali, storiche e filologiche* [6th ser.] **7**, 486 (1938–1942)].

124. Kepler was not aware that an Italian instrument dated 1590 had served as model for the first Dutch telescope, which was made in 1604, the very year in which Kepler's

"Optics" was published ["Journal tenu par Isaac Beeckman de 1604 à 1634," Cornelis de Waard, ed. (The Hague: Nijhoff, 1939–1953), III, 376; Harold Spencer Jones, in Henry C. King, "The History of the Telescope" (London: Griffin, 1955), p. VII].

125. In the letter of April 19 (NE X, 324:162), in the 1610 edition of the "Conversation" (p. 8:3), and in Frisch (F II, 492:6 up), "ingente" was mistakenly separated into two words "in gente," which were then mistranslated by Bryk (p. 329) as "in the practice of their profession."

126. There is no discussion of the antipodes in Ptolemy, who merely mentions the "so-called antichthones" ("Syntaxis," VI, 6; ed. Heiberg, I, 498:5–7; "Great Books," XVI, 202). Perhaps Kepler was thinking of the famous passage in Pliny: "There is a bitter quarrel between the intellectuals and the common people, who deny that human beings encompass the earth on all sides, and stand with their feet pointing toward one another, the zenith being alike for all of them, while their heels, wherever they are, in similar manner are directed toward the center. The common people ask why those who are located opposite them do not fall off, as though there were no reason for the latter to wonder why we do not fall off" ("Natural History," II, 65, 161). Even in his haste Kepler may not have substituted a Latin writer, Pliny, for a Greek author, Ptolemy. Instead he may have had Plutarch's "Moon" (924A) in mind: "Are there not antipodes who live on the earth and cling to it with their bottoms up like worms or bugs? Don't we ourselves stand slanting away from one another, like drunkards, instead of straight up and down?"

127. Kepler's "incredulis" (skeptical persons) was ungrammatically transferred by Bryk (p. 329) to Galileo's instrument, thereby making it "incredible."

128. Despite Bryk (p. 329), it was Kepler, not the emperor, who disparaged Della Porta. As Kepler informed a correspondent eight months later, "the emperor proposed to

accomplish, by means of mirrors and lenses, the reading of the tiniest letters many miles away as though they were close by" (GW XVI, 347:49–51). On June 20, 1604, Rudolph II sent Della Porta a letter in which he assured the Neapolitan that "when our arduous tasks of government permit, we enjoy the subtle knowledge of natural and artificial things in which you excel" [*Giorn. crit. filosofia ital.* **8,** 424 (1927)].

129. Despite Bryk (p. 330), Kepler's "specilla" (lenses) does not mean "telescopes," which were not discussed by Della Porta in his "Natural Magic."

130. "Don't think I'm unaware that I shall incur the censure of the physicists for saying, both now and heretofore, that the air has gravity or weight" (Kepler, "Optics;" GW II, 120:7–8). The air was so heavy, Kepler maintained, that it was dense enough to cast a shadow on the moon during an eclipse: "Entering into the computations of the astronomers as that which deprives the moon of the sun's light is the shadow, not of the earth (except at the center, which I shall discuss later on), but of the air which surrounds the earth" (GW II, 236:18–20).

131. "The air in itself is blue. It becomes bluer, the thicker it is, or the further it extends between a visible object and the eye, so that it is poured into the intervening space in a greater quantity of matter" (Kepler, "Third Man in the Middle," Thesis 49; GW IV, 191:34–36). Kepler wrote this work in the closing months of 1609, and dedicated it on January 3, 1610, just three and a half months before he sent the letter of April 19 to Galileo. In his "Epitome of Copernican Astronomy" Kepler reiterated his belief that "by reason of its own matter, according to the degree of its density, air acquires also a bluish color" (GW VII, 53: 29–30).

132. "The aether has its own substance." "The aethereal substance is not entirely non-material, but has its own proportion of density" (Kepler, "Optics;" GW II, 226:34;

260:37–38). Nevertheless, the "lowest celestial matter" would be in the vicinity of the moon only in the pre-Copernican astronomy. In that cosmology, the moon was the lowest of the heavenly bodies, and therefore near it would be the lowest celestial matter. But in the Copernican system, the sun was the lowest celestial body, whereas the moon was high in the heavens. Clearly, therefore, Kepler here unconsciously lapsed back into pre-Copernican terminology.

133. In the "Message" Galileo had ascribed to the moon an atmosphere, like the earth's, "of denser substance than the rest of the aether." Then he generalized: "We can properly hold the same opinion with regard to the other planets. Thus it seems by no means unthinkable to put around Jupiter too an atmosphere denser than the rest of the aether" (NE III, 70:17–18, 96:2–4; Carlos, pp. 26, 71; Drake, pp. 39, 58). Kepler's "incredibly tenuous" celestial substance, however, was reached by his own inference rather than under Galileo's guidance.

134. Before the publication of Galileo's "Message" in 1610, in his "Optics" of 1604 Kepler had assigned a certain density to the celestial substance or aether. But after perusing Galileo's "Message," in his "Epitome of Copernican Astronomy" (1618) Kepler said: "The distance between us and the fixed stars cannot be estimated. Yet the intervening aethereal substance, which is so extensive, transmits right down to us the light of the tiniest stars undiminished and with a differentiation of colors. This could not happen if the aether had a minimum either of density or of color. . . . Therefore if physics permitted, an astronomer could assume that the entire space of the aether is an absolute vacuum" (GW VII, 53:37—54:6). Yet in order to explain a certain phenomenon Kepler was prepared to suppose that the "aethereal substance . . . is sometimes a little denser" (GW VII, 508:3–4).

135. In the 1604 edition (GW II, 119:20–23).

136. In the "Optics" Kepler formulated the following Problem: "From the size of the refractions, to investigate the ratio of the media to each other, I mean, of air to water, as regards their density" (GW II, 119:13–14). He concluded that the density of air is to the density of water as "1:1,633,304,460. If anybody were up in the pure aether and made one cup of water out of it, and then 1,600,000, 000 cups of air, these would undoubtedly be equal in weight. And in a room or cube 12 feet long, wide, and high, no more matter is present when it is full of that very pure air which is next to the aether than there is in a tiny cube of water which extends ⅛th of an inch in all its dimensions" (GW II, 119:31–38).

137. "The simple refraction of a ray passing at an inclination of 80° from air into water is 19° 17′. The simple refraction of a ray passing at the same inclination of 80° . . . from the aether into the air is 59″" (GW II, 119:20–23).

138. In the letter of April 19 (NE X, 325:198), Kepler mistakenly wrote "maiorem," which he changed to "maiori" in the 1610 edition of the "Conversation" (p. 9:17). By making this change, he achieved the correct expression of his idea that aether:air is a much more disparate ratio than air:water. In the letter of April 19 he had unwittingly reversed this relationship, probably because he was hurrying to meet his deadline.

139. Only in the pre-Copernican astronomy was the moon "the lowest of the heavenly bodies." Here again, as we saw earlier in Note 132, Kepler lapsed into pre-Copernican terminology.

140. This parenthesis is not found in the letter of April 19 (NE X, 325:200). Kepler inserted it in the 1610 edition of the "Conversation" (p. 9:13 up), undoubtedly because he wanted to express more clearly his newly acquired belief that the aether's opaque density is so negligible as to offer not the slightest obstacle to telescopic observation of the remotest heavenly bodies.

141. Eight months later Kepler ruefully told a correspondent: "In my 'Conversation' I talked about increasing the number of convex lenses. I am discovering the most essential facts in practice too, but not with such success as we seek in this kind of instrument" (GW XVI, 352:247–249). Kepler made this admission in a letter dated December 18, 1610, wherein he referred to his "'Dioptrics,' which is now in the hands of the Most Serene Elector of Köln, who will arrange for its publication, I hope" (GW XVI, 350:183–185). In this little work, with which Kepler both initiated and christened a new science, he analyzed only three optical systems employing more than two lenses (3 convex lenses; 1 convex and 2 concave; 2 convex and 1 concave; GW IV, 389:6; 400:2–4; 405:7–10).

142. Eight months later Kepler told a correspondent: "You describe a tube having the shape of a trumpet, which is wider than its lower aperture. There is nothing here that is contrary to what I said. In my description I recognized that the outermost glass must be wider" (GW XVI, 348:115–117). Hence in the "Conversation" Kepler's "exteriores paulo latiores" means that the outer lenses are a little wider, and not that "the outermost lenses are placed a little further apart," despite Bryk (p. 331).

143. Kepler's "parallelorum" was mistakenly attached to the lenses by Bryk (p. 331). Had Kepler intended to describe the lenses as parallel, he would have written "parallelarum." By "parallelorum" Kepler means the rays which are parallel when they impinge on the outer surface of a lens, and before they undergo refraction. These refracted rays then converge. But Kepler's "intersectionis" was omitted by Bryk, who failed to realize that Kepler was tracing the path of rays. "Within the limits of the area where the previously parallel rays converge" (intra terminum intersectionis parallelorum) the eye will be placed, says Kepler. Instead, Bryk locates the eye "always in front of the center of all the parallel lens surfaces." But in Kepler's Latin

there is absolutely nothing corresponding to "always in front of the center."

144. In the 1604 edition (GW II, 172:27—173:6; 371:11—372:30).

145. The phenomenon later called "spherical aberration" was discussed by Kepler in the passages just cited in Note 144.

146. Not "1°," despite Bryk (p. 331), who overlooked Kepler's "dimidii."

147. In the letter of April 19 (NE X, 325:213), in the edition of 1610 (p. 10:5), and in Frisch (F II, 493:4 up), "34′" appears by an error, which was finally corrected to 30′ by Hammer (GW II, 294:17; 508) on the basis of Kepler's statement in his letter of December 18, 1610 (GW XVI, 350:200–201).

148. In the 1604 edition of the "Optics" (GW II, 175).

149. In the 1604 edition of the "Optics" (GW II, 174). In Proposition 18 Kepler analyzes a situation in which the middle of a straight object looks curved because it is magnified disproportionately.

150. In the 1604 edition of the "Optics" (GW II, 179).

151. "The crystalline lens's . . . posterior surface . . . has the shape of a hyperbolic conoid of revolution, that is, of a hyperbola rotated around its axis. . . . It is not spherical . . . but markedly protrudes and becomes oblong, as though it were rising up to form a cone" (Kepler, "Optics;" GW II, 151:5–13). "The crystalline humor of the eye is a convex lens in the form of a hyperbola. . . . The experience of the anatomists establishes also that it is hyperbolic in shape on its posterior side" (Kepler, "Dioptrics;" (GW IV, 372:5, 8–10). Actually, the posterior surface of the crystalline lens has a convex spherical form over a small region near the axis, and outside this region

it becomes flatter [Hugh Davson, ed., "The Eye" (New York and London: Academic Press, 1962), IV, 102].

152. In the 1604 edition of the "Optics" (GW II, 102).

153. Kepler's "machinamenta optica" (optical devices) consisted of arrangements of lenses, and had nothing whatever to do with gear wheels or engines, despite Bryk (p. 331: Triebwerke); see GW II, 93:32; 104: margin.

154. In the 1604 edition of the "Optics" (GW II, 93, 104).

155. In the 1604 edition of the "Optics" (GW II, 101:4–7): "What single and continuous surface of water, in receiving all the rays emanating from some nearby point and diverging in various directions, will refract them, stop them from diverging, and send them ahead parallel?"

156. In the "Optics," after demonstrating this property of a hyperbolic refracting surface, Kepler added the following Corollary: "This explains nature's purpose with regard to the posterior surface of the crystalline lens in the eye. Nature wanted all the rays entering the pupil from any visible object to converge in a single point on the retina" (GW II, 179:17–21).

157. In the letter of April 19 (NE X, 325:225–226) Kepler made the first two angles 32° and 8°. Then he changed these angles to 27° and 9° in the published "Conversation" (ed. 1610, p. 10:12 up). This change seems to be connected with his pronouncements a few months later in his "Dioptrics" that "the refractions of crystal and glass are approximately the same" and "the angle of refraction in crystal is . . . almost exactly ⅓ of the inclination in air" (GW IV, 357:14, 19–20).

Nevertheless, this whole statement is so obscure that Hammer, who edited both the "Optics" and the "Dioptrics" in GW, was doubtful about the meaning of Kepler's reference to the third angle of 30½° (GW IV, 508). In an effort to make sense out of what precedes, Hammer forsook the customary meaning of "contingentem" in Kepler (tangent; e.g., GW II, 77:12–13, 15; 96:11; 98:22, 26–27; 103:19, 23; 110:6; 130:27) and transformed it into "perpendicular," without citing any instance of contingentem = perpendicular in Kepler. What Kepler is talking about so obscurely here seems to be related to what emerged later as Proposition LIX of the "Dioptrics." Eight months after he prescribed a hyperbolic lens in the "Conversation" for its usefulness in eliminating spherical aberration, Kepler informed a correspondent that the theoretical advantage could not be attained in practice:

> All our artisans agree in asserting that a hyperbolic lens cannot be turned on the lathe. For, the grooves become circular as the hyperbolically shaped scraper's innermost projection, being the axis of the rotating conoid, rubs practically nothing away, whereas the outermost parts scrape away very much material. Nor can this situation be remedied by varying the contacts. For, a portion of a sphere can be applied everywhere to the hollow part of the blank which is being ground down by the same spherical surface, both at its center or axis and at its outermost edge. This is not the case in the usual manufacture of conoidal shapes. For, only the projecting tip presses into the center or bottom of the hollow blank. . . . But it will not be difficult for Galileo to devise a new kind of machine by which also the bottom of the concave blank may be dug out more vigorously than it is usually done by the almost stationary parts around the axis of the motion. Such a process I too have at hand already, and if I succeed with what I have started, perhaps I shall undertake to make it with my own hands (GW XVI, no. 600:229–247).

158. Kepler's "unius puncti" (from a single point) was omitted by Bryk (p. 332), who thereby missed the distinctive feature of Kepler's point-by-point analysis of vision.

159. Kepler's "umbonem" means his optical lens, not the eye (despite Bryk, p. 332).

160. Kepler's "in puncto, proxime crystallinum" means "at a point close behind the crystalline lens," not "in a point of the crystalline lens," despite Bryk (p. 332). He had just previously equated Kepler's "post crystallinum" correctly with "after the passage through the crystalline lens." But since the rays have already passed through the crystalline lens, how can they then meet "in a point of the crystalline lens"?

161. When the light emanating from a point impinges on the retina in an area, not in a point, the result is not the "clearest vision," which was defined by Kepler in his "Optics" as occurring "when all the light from the same point, in whatever quantity it spreads out through the width of the cone that is admitted by the pupil of the eye, is brought together by two refractions, one in the cornea, the other in the posterior surface of the crystalline lens, and very powerfully lights up a single retinal point, the very opening of the nerve that carries the visual faculty or spirit, a point which cannot be reached by any other rays from any other luminous point" (GW II, 154:31–37).

162. Eight months later Kepler explained to a correspondent that there was a labor-saving alternative to changing the concave lens for every observer: "Next comes the tube, which holds the concave lens. This tube may be drawn out or extended. You say that you do not understand the purpose of this feature. I shall explain it to you. It is simply this. Unless the tube is made extensible, the correct distance between the lenses cannot be found for the purpose of viewing remote objects. A second purpose is this. Since eyes differ in strength, therefore a variable distance between the lenses could help everybody. For, one man pulls the tube out further than another, in order to see clearly." "If the concave lens is separated from the convex lens by the same distance and is so fixed that it cannot be moved

out of its position, it does not suit everybody's eyes, but with such an unadjustable tube, the concave lenses will have to be changed. However, a most useful short cut is provided by the opportunity to vary this distance by means of a tube that can be pulled out and pushed together. For in this way the same concave lens in a variable position takes the place of many concave lenses in one and the same position" (GW XVI, no. 600:150–155, 222–227).

163. In the 1604 edition (GW II, 182:5–8): "The cone emanating from so remote a point will come to an end before it reaches the retina, and as it continues on, it will spread out again. Therefore, with some width it will impinge on the retina, and the cones will throw one another into disorder and confusion."

164. "For the purpose of ascertaining the magnifying power of the instrument with little effort, anybody may cut out of paper two circles or two squares, one of which is 400 times bigger than the other. This will be the case when the diameter of the larger circle is 20 times longer than the diameter of the other circle. Then attach both surfaces to the same wall, and look at them simultaneously from a distance. The smaller circle will be observed with one eye applied to the telescope, but the larger circle with the other eye unassisted. For this may be done comfortably at one and the same time with both eyes open. Both figures will appear to be of the same size if the instrument magnifies objects in the desired proportion" (Galileo, "Message"; NE III, 61:23–32; Carlos, p. 12; Drake, p. 30).

165. To the outer of the two lenses, or the object-lens, of his telescope, Galileo said, "we shall adapt diaphragms perforated with apertures, some bigger, but others smaller. By attaching now this diaphragm, now that one, as occasion requires, we shall set up as we please different angles containing more or fewer minutes. By their aid we shall be able conveniently to measure the distances between stars which are separated from each other by some minutes,

with an error of less than one or two minutes" (NE III, 62:6–12; Carlos, p. 14; Drake, p. 31).

166. Some information about the relations between Johannes Pistorius (1546–1608) and Kepler may be gleaned from the latter's correspondence. For instance, Kepler informed a friend: "After I came to the attention of Pistorius here [at Prague], as he is a lover of learning, he showed me Hero's book on 'Pneumatics,' in which I immediately pointed out . . . errors to him. . . . Since he could not figure out its badly designed drawings and defective text, he ordered me to lend a hand" (GW XIV, 346:142–145, 161–163). When Kepler received 100 thalers for dedicating his "Optics" to Rudolph II, he attributed the emperor's generosity in part to Pistorius' recommendation (GW XV, 68:4–7). With regard to the dispute between Kepler and Tycho Brahe's son-in-law over the use to be made of the deceased Danish astronomer's observations, Kepler said: "I don't know whether anybody at court was aware of our quarrel, with the single exception of Pistorius" (GW XIV, 282:11–12). After the two contending parties signed a formal agreement, Kepler reported, "Pistorius was designated by the emperor as the man to whom I owe an accounting of my time. Since he holds this authority, I can hide nothing from him of my professional studies, whether public or private" (GW XV, 222:16–19). When Kepler finished writing his "New Astronomy" and was wondering from whom he would obtain the money to publish it, "Pistorius aroused hope in me by mentioning to the emperor that I need the sum of 800" (gulden; GW XV, 300:187–188); Kepler's "nuncupata Caesari summa" means that "the sum was mentioned to the emperor" by Pistorius, not that "the emperor made an announcement about the necessary 800 gulden" (despite Caspar-Von Dyck, I, 261). The Pistorius who was designated by Kepler in 1625 to be his agent in a financial transaction (GW XVIII, 250:19–22) cannot be Johannes Pistorius, who died in 1608, and is

more likely to be Jeremiah Pistorius (despite GW XVIII, 590).

A little over a year before he died, Johannes Pistorius informed Kepler that he was suffering from a grave illness from which he did not expect to recover, and that he welcomed the prospect of death with a clear conscience (GW XV, 412). In a bitter answer Kepler urged Pistorius to "confess to God your concealed sins, your unconscious sins, and your belief that you were practicing the worship of God by attacking certain persons violently. . . . With my innermost feelings deeply stirred, this . . . is what I wanted to reply to the part of your letter concerning your illness and imminent death. I hope that you will receive these remarks in written form as you used to receive them when we talked and argued about the same subject. . . . I ask you to destroy this letter after you have read it" (GW XV, no. 431:34–36, 53–59). As a Roman Catholic zealot, Pistorius had evidently often discussed theological questions with Kepler perhaps in an effort to induce the Imperial Mathematician to follow in the footsteps of his official supervisor by becoming a convert to Catholicism. As the coarsest of the contemporary Catholic controversialists, Pistorius had achieved considerable notoriety for the viciousness of his onslaughts, both in public debates and in printed polemics, against his former associates and church. For a one-sided defence of Pistorius' tempestuous career from a militantly Catholic point of view, see Johannes Janssen, "History of the German People at the Close of the Middle Ages," English translation (London and St. Louis, 1896–1925), X, 116–150.

In the field of historical scholarship, Pistorius' publications have more enduring worth. Thus he contributed an improved edition of Robert the Monk's "History of Jerusalem" to Justus Reuber's "Veterum scriptorum qui caesarum et imperatorum germanicorum res per aliquot saecula gestas litteris mandarunt tomus unus" (Frankfurt, 1584). Pistorius published for the first time many manuscripts dealing with the medieval history of three countries: Poland ("Polonicae historiae corpus," Basel, 1582); Germany ("Illustrium veterum scriptorum, qui rerum a germanis per multas aetates gestarum historias vel annales posteris reliquerunt, tomi duo," Frankfurt, 1583–1584; "Rerum germanicarum veteres iam primum publicati scriptores vi," Frankfurt, 1607); and Spain (Volume III, Frankfurt, 1606, of Andreas Schott's "Hispania illustrata"). In addition, Pistorius' "Genealogy of the Kings of Hungary, Derived from the Best Writers" was included in Jacques Bongars' "Rerum hungaricarum scriptores varii" (Frankfurt, 1600).

Kepler referred to Pistorius as "that highly learned and very industrious author of a thick book" on astrology (F VIII, 340:24), and recalled "having seen a horoscope of the emperor made by Pistorius" (GW XVI, 384:25). Less common was Pistorius' devotion to the cabalistic art, on which he published a collection of older writings (Basel, 1587). Cabalistic ideas formed the basis of his own tract on the plague (Frankfurt, 1568), and his other medical works were founded on even less substantial underpinnings [Lynn Thorndike, "A History of Magic and Experimental Science" (New York, 1923–1958), VI, 461–463]. All in all, a certain amount of good-natured exaggeration may be suspected in Kepler's description of Pistorius as "that master of all the sciences."

167. Kepler's "non una vice" (not once = more than once) was mistranslated by Bryk as "once" (p. 332).

168. Kepler's "perspicillorum" (lenses) was mistranslated by Bryk as "telescopes" (p. 332). Closely connected with this error is Bryk's mistranslation of Kepler's "subtiliorem" (more exact) as "new." Thus Pistorius' prediction that some day lenses would permit more precise observations was transformed by Bryk's double error into a prediction that telescopes would permit a new method of observation.

169. Kepler's "in parte" (in part) was omitted by Bryk, who replaced it by "admirably" (p. 333). As a result, Bryk misattributed to Kepler the statement that Pistorius' prediction (of the telescope!) turned out to be completely correct. In actual fact, Kepler stated that Pistorius' prediction of more precise observations by means of lenses was partly correct.

170. "I called this instrument 'the astronomical sextant' because with its arc it embraced the sixth part of a circle" or 60° [Tycho Brahe, "Preliminary Exercises of the Renovated Astronomy," Chapter 4 = "Tychonis Brahe dani Opera omnia" (Copenhagen, 1913–1929), II, 331:39–40; cited hereafter as "TB"]. Brahe died before the printing of his "Preliminary Exercises" was finished, and as his successor Kepler took charge of the volume. For the construction and use of the astronomical sextant, see "Tycho Brahe's Description of His Instruments and Scientific Work" (Copenhagen, 1946), pp. 24–27, 72–79.

171. "When the lower edge of the sun grazes the horizon, its refraction will be 34′" (Kepler, "Optics;" GW II, 122:33–34). This conclusion that at 0° of altitude the refraction amounted to 34′ was taken over by Kepler from Brahe (GW II, 112:34, 114:4, 117:50; Brahe, "Preliminary Exercises": TB II, 64:7).

172. Kepler's "solis" (by themselves = without the telescope) was mistranslated by Bryk as "only" (p. 333). In other words, Kepler's statement that Brahe's instruments, without being further improved, could make accurate measurements of 60° and 34′ was thereby transformed by Bryk into the dreadful nonsense that "only from Brahe's instruments do people learn to understand what an arc of 60° and what 34′ mean."

173. In his "Optics," Chapter 11, Kepler described the construction of this instrument (Problem I), and its use in

measuring the apparent diameter of the moon (Problem IV; GW II, 288–290, 294).

174. Kepler's "expoliendum" (improving) was mistranslated by Bryk (p. 333) as "completing the writing." Actually, Kepler never completed the writing of his "Hipparchus," which remained an unfinished torso at the time of his death.

175. Because this word was overlooked by Delambre, he misunderstood Kepler to be referring to the ancient Greek astronomer Hipparchus, instead of to Kepler's own unfinished "Hipparchus" ("Histoire de l'astronomie moderne," I, 471).

176. Bryk failed to realize that "the sizes and distances of the three bodies, sun, moon, and earth" was the sub-title of Kepler's "Hipparchus" (F III, 520). This was a work which Kepler neither finished nor published. It was not included in Kepler's "Rudolphine Tables" (Ulm, 1627), despite Bryk, p. xliii. Perhaps Bryk misunderstood Kepler's statement that his "Hipparchus" "was published, if you look at the effect, in the 'Rudolphine Tables,' especially in the aforementioned pages, that is, in the parallaxes of the sun and moon, the radii of the shadow, and the rules for determining them. It was not published, if you want the theorems. But there will be an edition very soon, if God permits me to live" (Kepler, "Johannes Schreck's Letter, with Johannes Kepler's Brief Comment," Zagan, 1630; F VII, 678:25–28). There never was an edition in Kepler's lifetime, even though he announced it as early as the Peroration of his "Optics," where he said: "The book's principal purpose will be to investigate the sizes and distances of the three bodies, sun, moon, and earth. This is the same material which Hipparchus . . . studied . . . in a special work. May it therefore be a happy and fortunate omen that my book should be entitled 'Hipparchus'" (GW II, 378:24–28). This situation was misunderstood by Delambre, who declared that "Kepler's intention in

writing his 'Hipparchus' was to present a sort of extract from the 'Mathematical Syntaxis' in order to restore to the true author everything which had been borrowed from him by Ptolemy" ("Histoire de l'astronomie moderne," I, 592).

177. Kepler's "digitosque in luna deficientes" means "the eclipsed digits in the moon." "The entire body of the moon is divided into twelve parts or digits" (GW II, 207: 36–37) for the purpose of describing what portion of the moon's surface was blacked out in a partial lunar eclipse. This measurement by digits was evidently unfamiliar to Bryk, who mistranslated Kepler's "digitosque in luna deficientes" as "the incorrect determinations of the size of the moon" (p. 333).

178. Kepler's "in tabellam" was omitted by Bryk (p. 333), who thereby left out the safety feature of Kepler's apparatus for observing the sun.

179. Two years later Kepler forgot to follow his own advice, as he informed Wackher: "Early this morning, when there was a heavy overcast, I turned my instrument toward the sun, with its upper lens open no wider than the head of a pin. And here I am, although an hour has already passed, with every single letter that I am writing fiery red. My eyes burned and itched painfully, even though I protected myself with dark glass, and endured the sun's brilliance for scarcely the twinkling of an eye" (GW XVII, 8:61–66).

180. In "A Singular Phenomenon, or Mercury in the Sun" Kepler announced that he had observed a transit of Mercury across the face of the sun on Monday, May 18/28, 1607 (GW IV, 75:15–17; 92:8–9). But in his "Sunspots" (Rome, 1613) Galileo remarked: "I have no doubt that Kepler, as a very keen and uninhibited mind, and as a friend much more of the truth than of his own opinions, will be thoroughly convinced that such black areas seen in

the sun were some of the sunspots, the conjunctions of Mercury [with the sun] having merely provided the occasion for making more intensive and precise observations at those times" (NE V, 198:28–33; Drake, p. 133). For several years no public retraction of his mistaken claim that he had observed a transit of Mercury was issued by Kepler "because there was no other place for it than here, where among the other planets I discuss Mercury too. To have written a special book on this unimportant subject would have been senseless" (Kepler, "Ephemerides for 1617–1620," Linz, 1617–1619, p. 18, misnumbered 21; F II, 110:12–10 up). But Kepler remarked that he had "written a letter to Galileo about this matter" ("Ephemerides," p. 20; F II, 787:23–22 up). Presumably this was the letter which Kepler said was "in transit at the same time as Galileo's letters" about the "Sunspots." Kepler continued by asking his challenger: "Do you think that the torturer's thongs are needed to extort confessions in this matter, or entreaties to coax them out of people who fight not for glory but for the truth?" ("Ephemerides," p. 18, misnumbered 21; F II, 110:18–13 up). Unfortunately Kepler's private letter to Galileo admitting his misinterpretation of a sunspot as Mercury has not been found among the Kepler or Galileo papers. But Frisch's assertion (F II, 787:18–17 up) that "Kepler seems to have sent absolutely no letters to Galileo from 1611 to 1615" was based on a gross error in chronology. Galileo's report to Giuliano de' Medici that "it's been a long time since I've heard from Kepler" (NE XI, 335:12–13) was misdated by Frisch on June 23, 1615, whereas Galileo actually made this statement three years earlier, on June 23, 1612. In other words, Galileo's comment about Kepler's long silence was made nearly half a year before Galileo wrote his third letter on "Sunspots," in which he publicly disputed Kepler's interpretation of the 1607 observation. Therefore Kepler's silence had nothing whatever to do with Galileo's correction of his misinterpreted observation. The author on whom Drake (p. 118) relied for this whole matter confused the year (1607) in which Kepler made his misinterpreted observation with the year in which he published his little book about the "Singular Phenomenon" (Leipzig, 1609).

181. "That comets are for the most part far above the moon and way up in heaven was magnificently demonstrated by Tycho Brahe of illustrious renown" (Kepler, "Complete Report on the Comet of 1607"; GW IV, 59:19–20). To prove that the comet of 1577 was supralunar, not sublunar, Brahe had relied on parallax measurements: "An estimate of the comet's distance from us in the direction of the firmament can be taken only from the parallax, if it has any. For if it had a greater parallax or diversity of aspect than the moon, which is next to us, then we would have to conclude that it was even nearer to us than the heaven in which the moon runs its course" (Brahe's German pamphlet "On the Comet of 1577"; TB IV, 387:17–22).

182. GW II, 216:36—221:17.

183. Kepler's "Schema" (sketch, drawing) was mistranslated by Bryk (p. 334) as "procedure."

184. In the 1604 edition; GW II, 217.

185. Kepler's "limbum lunae" (moon's limb or apparent edge as seen from the earth) was mistranslated by Bryk (p. 334) as "moon's disk." But in the "Optics" (GW II, 217: 13–17) Kepler reported that the moon's "outside edge was very bright and clear all around . . . whereas the middle was one continuous spot or shadowy region." Hence the moon's disk did not appear very bright throughout, despite Bryk.

186. "The side of the moon which faces us . . . I divide into two parts, one brighter and the other darker. The brighter part seems to encircle the entire hemisphere"

(Galileo, "Message"; NE III, 62:18–21; Carlos, pp. 14–15; Drake, p. 31).

187. "Those darkish and very large spots are obvious to everybody, and have been seen by every age. Therefore I shall call them 'big' or 'ancient,' as distinguished from the other spots, which are smaller in size yet so crowded together that they are dispersed over the entire surface of the moon, but especially the brighter part. These, however, have been observed by nobody before me" (Galileo, "Message"; NE III, 62:22–28; Carlos, p. 15; Drake, p. 31).

188. "Optics," 1604 edition; GW II, 177:23—178:27.

189. GW II, 189:7–23.

190. Of Book 17 of his "Natural Magic."

191. "Now, however, I shall explain what I have hitherto always kept silent about, and have thought should not be spoken of. If you will place a crystalline lens in the aperture [of the dark chamber], you will at once see everything more clearly, the faces of the people walking around, colors, clothing, gestures, and you will behold everything, just as if you were viewing it from close up, with such great delight that those who have had this experience can never wonder enough about it"; English translation, pp. 363–364.

192. The apparatus described in the "Conversation" has a spherical lens inserted in the aperture, and in this respect differs from the arrangement utilized by Kepler in the "Optics." This had no lens in the aperture, which was merely a narrow opening in an opaque screen placed just in front of a glass ball filled with water. This whole arrangement was intended by Kepler to match the human eye: the opening corresponded to the pupil; the opaque screen to the sclera; the glass ball, to the interior transparent refractive media; and the sheet of paper to the retina.

193. "On the fourth or fifth day after conjunction [of sun and moon, or new moon], when the moon presents itself to us with shining horns, the terminator dividing the region in shadow from the illuminated region does not extend evenly in an oval line . . . but is indicated by an uneven, irregular, and quite wavy line" (Galileo, "Message"; NE III, 63:4–8; Carlos, pp. 15–16; Drake, p. 32).

194. "If the entire circle of illumination could be seen, it would look like a perfect ellipse. But because half of it or more than half is hidden behind the body of the moon, what is seen is only an arc of an ellipse" (Kepler, "Optics," 1604 edition, p. 244; GW II, 215:26–28).

195. "Very many bright excrescences, as it were, extend beyond the boundary of light and shadow into the dark region. On the other hand, shadowy patches invade the region of light. Indeed a large number of small blackish spots, completely separate from the region of shadow, is scattered throughout almost the entire region already suffused with sunlight, the only exception being the part containing the big ancient spots. I have noticed, moreover, that all the small spots, which were just mentioned, always agree in having their dark areas confronting the position of the sun, but in being crowned on the side away from the sun by brighter boundaries, like shining heights. On the earth, however, we have a very similar sight around sunrise, when we see the valleys not yet suffused with light, but the mountains surrounding them on the side away from the sun already gleaming in splendor. In addition, just as the shadows in the hollows on the earth shrink while the sun climbs higher, so too those spots on the moon lose their shadows while the illuminated region expands" (Galileo, "Message"; NE III, 63:9—64:3; Carlos, pp. 16–17; Drake, p. 32).

196. Kepler lived in Styria from 1594 to 1600 as the teacher of mathematics in the high school at Graz, the capital of Styria, and as the "mathematician of the duchy of Styria."

197. Kepler's "angustissimis" (very narrow) was mistranslated by Bryk as "vast" (gewaltigen, p. 335). Perhaps Bryk misread "angustissimis" as "augustissimis."

198. Kepler's "aheni" (bowl) was mistranslated by Bryk as "insurmountable" (p. 335).

199. Modern astronomers are convinced that there are no rivers on the moon, which "cannot . . . maintain any liquid on its surface. . . . No liquid—or even solid—water could be present almost anywhere on the moon, except possibly for very short intervals of time. The surface of the moon is thus apparently bone-dry, and has been so from time immemorial. No feature visible on the surface of the moon could thus have been formed, or modified, by the effect of running water, or of freezing and melting water" [Zdenek Kopal, "The Moon," 2nd ed. (London: Chapman & Hall, 1963), pp. 18–19].

200. "This [part of the] moon's surface . . . is marked by spots, like the blue eyes of a peacock's tail" (Galileo, "Message"; NE III, 65:9–10; Carlos, p. 19; Drake, p. 34).

201. Kepler's "propter" (on account of) was mistranslated as "near" by Bryk (p. 335), who failed to see that "propter" here is exactly like the "propter" which he rendered correctly at Note 199, just above.

202. Kepler's "plerasque" (for the most part) was turned into its opposite "only a few" by Bryk (p. 335). Discussing the "almost bewildering array of formations and structures" on the surface of the moon, Kopal says: "the dominant type of formation among them, and by far the most numerous on any part of the moon, appear to be ring-like walled enclosures commonly called the 'craters.' They occur almost everywhere on the moon . . . in truly prodigious abundance, giving the lunar surface an appearance of a pock-marked face" ("The Moon," 2nd ed., pp. 29–30).

203. Kepler guessed wrong. "The moon consists of material which is very similar to that constituting the outer crust of our own planet" (Kopal, "The Moon," 2nd ed., p. 20).

204. Of the 1609 edition. In the 1610 edition of the "Conversation" (p. 14:12 up) this page number was misprinted as "157." Frisch (F II, 496:11) deleted the page reference, and GW IV, 297:21 returned to the correct reading of the April 19 letter (NE X, 328:322).

205. "The moon's main motion, the monthly revolution, . . . comes entirely from the earth as its source. . . . Therefore consider how our earth imparts motion to the moon. While this earth of ours, and together with it its incorporeal emanation, rotate 29½ times around its axis, in that same time this emitted emanation can drive the moon only once around in a circle in the same direction in which it is preceded by the earth. But strangely enough, in any interval of time the center of the moon describes around the center of the earth a line which is twice as long as the line described by any point lying on the equator, a great circle on the surface of the earth. For if equal distances were described in equal times, the moon would have to return to its starting place in 60 days, since its orbit is 60 times as wide as the terrestrial globe. Truly, so great is the force of the earth's incorporeal emanation, and the moon's body is undoubtedly of low density and weak resistance" (Kepler, "New Astronomy"; GW III, 245:9–24). Kepler's conception of the earth's daily rotation as the moon's motor, although later proved wrong, formed part of his introduction of physical causes into astronomy. He asked the question "What makes the moon move?" His answer, "the earth's rotation," proposed a physical cause for the first time in the history of astronomy. The moon's orbital velocity averages about 2300 miles an hour, while the speed of the earth's rotation at the equator is about 1000 miles an hour, so that Kepler's approximate ratio of

2:1 was quite good. Equally good was his judgment about the moon's low density (which is about three-fifths of the earth's density).

206. This parenthesis was not present in the letter of April 19 (NE X, 328:326), but was inserted by Kepler in the published version of the "Conversation" in the interest of greater clarity.

207. In the lower portion of the moon Galileo's "Message" reported a concentration, not of peaks, but of spots: "When the moon was approaching first quarter, . . . there was a large number of dark spots in both horns, but especially in the lower one" (NE III, 64:22, 65:2–4; Carlos, pp. 18–19; Drake, pp. 33–34). Presumably Kepler's substitution of peaks for spots was due to the haste with which he worked.

208. "Optics," edition of 1604.

209. "Just as our earth has certain big gulfs, so we human beings think that the moon too is penetrated by great chasms and clefts containing water or murky air" (Plutarch, "Moon," 935C).

210. "This is what Plutarch says. In this respect I do not agree with him. It is more reasonable to believe that the bright parts in the moon are seas, whereas the spotted parts are land, continents, and islands" (Kepler, "Optics"; GW II, 220:20–23).

211. This reference in the spring of 1610 to the summer of 1609 permits us to date Kepler's composition of his "Dream or Posthumous Work on Lunar Astronomy." This work, as its title indicates, was published after Kepler's death, in 1634, as Bryk correctly stated on pp. xliii and xlvii, and not in 1628, before Kepler's death, as Bryk incorrectly stated on p. i.

212. "I made the aspect of the Old World darker because I thought . . . that land is dark. . . . The half in which

the New World lies I called a 'little lighter' in aspect . . . because it has more seas and great expanses of ocean" (Kepler, "Dream," Notes 154–155; F VIII, 58).

213. "Optics," edition of 1604.

214. "In the year 1601, when I had returned to Styria for the sake of a small business matter, I climbed quite a high mountain, called Schöckel. . . . As I watched from this mountain, the earth presented itself with unbelievable clarity. . . . The Mur River, cutting a groove through the middle of the area, . . . by its extraordinary splendor easily surpassed the misty clarity of the land. . . . These observations furnished evidence to my eyes that a greater brilliance usually arises from water than from land" (GW II, 220:31—221:11).

215. "Optics," edition of 1604, p. 252.

216. "A contributing cause [of the river's brightness], however, was the daytime clarity of the air. Since this surrounded the river on all sides, its rays could likewise be reflected from the water's smooth surface in all directions, and thus also to me on the mountain" (GW II, 221: margin).

217. "All water in the course of time . . . gradually turns black" (794b 26–28 in the collected writings of Aristotle; "On Colors" is now believed to have emanated from a successor of Aristotle rather than from the master himself).

218. "Watery surfaces . . . partake of the color black less than the earth does" (Kepler, "Optics"; GW II, 220:24, 27).

219. The most famous work by this Greek satirist of the second century after Christ is the "True Story" which, as Kepler revealed in the "Dream," Note 2, he "chose for the purpose of mastering the language" (F VIII, 40:14–13 up).

220. According to Kepler, Lucian's cheese-like land was the moon, not the earth, despite Bryk (p. 336). In fact, this parenthesis was worded more simply in the letter of April 19: "as Lucian compared the moon to a cheese" (NE X, 329:350–351).

221. Kepler wrote the "Conversation" so fast that he did not take the time to refresh his memory. For in the "True Story" Lucian did not say that the moon is a cheese-like land. He did say that his voyagers "entered a sea, not of water, but of milk; and an island in it looked white. . . . The island was a very big solid cheese, as we found out afterwards by biting into it" [Lucianus, Nils Nilén, ed. (Leipzig, 1906), p. 170:3–7]. The inhabitants of the moon, according to Lucian, "when they work or exercise, sweat milk all over their bodies, so that cheese too can be made from it" (ed. Nilén, p. 149:11–13). In his unrefreshed recollection Kepler transformed the end product of the moondwellers' sweat into the moon's substance. A recent English translation of the "True Story" was included in Lucian, "Satirical Sketches," translated by Paul Turner (Baltimore: Penguin, 1961), with our passages at pp. 261 and 273.

222. Kepler's "humilitatem" (low elevation) was mistranslated as "moist" by Bryk (p. 337), who may have misread "humilitatem" as "humiditatem."

223. "Before last quarter this same spot is seen surrounded by certain blacker boundaries" (Galileo, "Message"; NE III, 65:34–35; Carlos, pp. 20–21; Drake, p. 35).

224. Kepler's term "maria," which he contributed to selenography in the "Conversation," is still used by astronomers, even though they regard the maria as bone-dry flat lands, not as seas.

225. In the edition of 1604.

226. "When the moon presents its disk divided in half, it shows a dividing line that is uneven and somewhat wavy.

This proves that some of its parts are low, and others higher" (GW II, 218:25–27).

227. Of the 1604 edition of the "Optics."

228. In the eclipse of February 11/21, 1598, Kepler reports, the moon was seen "with certain bright streaks penetrating into the shadow, as though it were torn or lacerated, and what should have been the arc dividing the part in shadow from the bright part, by reason of its unevenness, looked like the edge of a broken stick" (GW II, 219:35–37).

229. Kepler's "iam" (at that time) was mistranslated as "only" by Bryk (p. 337).

230. "Watery surfaces . . . have the property of reflecting sunlight in almost all directions. . . . For the less black things are, the whiter they are. But white things have the property of absorbing and reflecting light" (Kepler, "Optics"; GW II, 220:24–30).

231. "In the large . . . spots . . . only here and there do some brighter little areas abound. . . . Within these same big spots are seen certain little areas, some rather bright, and others even very bright" (Galileo, "Message"; NE III, 65:13–16, 69:1–2; Carlos, pp. 19, 23; Drake, pp. 34, 37).

232. Kepler's "planis" (conspicuous) was mistranslated as "small" by Bryk (p. 338).

233. "The space which is almost in the center of the moon is occupied by a certain hollow that is bigger than all the others and perfectly round in shape" (Galileo, "Message"; NE III, 68:1–3; Carlos, p. 21; Drake, p. 36).

234. "According to the Pythagoreans, the moon looks earth-like because, like our earth, it is inhabited all around by bigger animals and more beautiful plants," Pseudo-Plutarch, "The Opinions of the Philosophers," II, 30. Like many other authors, Kepler did not hesitate to ascribe to Pythagoras himself views attributed to the Pythagoreans.

235. The passage quoted in the preceding Note may have been brought to Kepler's attention by Mästlin, who in a letter to Kepler on April 28, 1613, recalled having cited it previously (GW XVII, 57:146–149). In Kepler's time "The Opinions of the Philosophers" was regarded as a genuine work of Plutarch, but it is now thought to have been erroneously attributed to him. In his authentic "Moon" (937D–940F) Plutarch discussed the question whether that body is inhabitable. But Kepler tells us ("Dream," Note 2; F VIII, 40:9–8 up) that he first encountered Plutarch's "Moon" in 1595, after he had left Tübingen. Hence when he says in the "Conversation" that at Tübingen in 1593 he followed in the footsteps of Plutarch, he is referring to the non-authentic "Opinions of the Philosophers," not to the authentic "Moon."

236. Kepler's "scripta" (written) was mistranslated by Bryk (p. 338) as "published." The disputation was never published, and in fact has not survived as a separate work.

237. The Tübingen disputation of 1593 was incorporated by Kepler, in the summer of 1609, in his lunar geography, which was published posthumously as his "Dream." This contains a discussion of living things on the moon in the closing section (from Note 211 to Note 221). This closing section of the "Dream," as is made clear by the present statement in the "Conversation," originally formed part of the (now lost) 1593 disputation. This dealt with the moon, and was mistakenly identified by Hammer (GW IV, 509) with another disputation which Kepler wrote at Tübingen about the earth's rotation (GW I, 9:16–17). But Kepler composed a number of disputations or dissertations at Tübingen ("Dream," Note 2; F VIII, 40:19), and he specifically refers to "the disputation about the moon written by me" (GW XIII, 39:243).

238. In the 1604 edition: "Let us too speak in jest, in company with Plutarch. Among us it happens that men and beasts conform to the type of their region or province.

Therefore the creatures living on the moon will have much more massive bodies of a much tougher calibre than ours" (GW II, 220:6–9).

239. See the text near Note 211, above.

240. In the "Optics" Kepler had insisted that the moon's "mountains are bigger in proportion to its globe than are the earth's mountains in proportion to it" (GW II, 220: 5–6).

241. According to Pseudo-Plutarch's "Opinions of the Philosophers," II, 30, as Kepler undoubtedly knew, "the creatures living on the moon are 15 times stronger [than their terrestrial counterparts] . . . and their day is correspondingly long."

242. "Why don't we see unevenness, roughness, and waviness in the waxing moon's outermost periphery which faces west, in the waning moon's other semicircular edge which faces east, and in the full moon's entire circumference? Why do they appear, on the contrary, perfectly round and circular, and unspoiled by any swellings or indentations?" (Galileo, "Message"; NE III, 69:15–20; Carlos, p. 24; Drake, p. 38).

243. Of the 1604 edition of the "Optics": "It seemed . . . as though something was missing in the circularity of the outermost periphery" of the moon in the lunar eclipse of February 9–10, 1599, new style (GW II, 219:11–13). In the letter of April 19 Kepler said that his statement on page 249 had been based "on an eclipse" (NE X, 330: 399–400), but he deleted this expression in the published version of the "Conversation" (1610 ed., p. 17:6 up).

244. Of the 1604 edition of the "Optics": "If you look carefully at the moon when it is full, it seems perceptibly to be lacking in roundness" (GW II, 220:1–2).

245. "If the protuberances and indentations in the body of the moon extended only along the arc of the circle which

bounds the hemisphere visible to us, then the moon could, indeed should, look to us, as it were, like a toothed wheel, terminating in a bumpy and sinuous edge. On the other hand, there may be not merely a single series of heights arranged only along the circumference, but very many ranges of mountains together with their gaps and chasms may be distributed around the outermost limb of the moon. These may exist not only on the visible hemisphere, but also on the side of the moon that is turned away from us (although near the boundary of the hemispheres). In that case the eye, viewing them from a distance, will not be able to perceive the difference between the heights and the indentations. For the gaps between the mountains which lie in the same circle or in the same range are hidden by the interposition of other peaks situated in various other rows. This will be especially true if the observer's eye is located in the same straight line as the summits of the said peaks. . . . On the moon and around its perimeter there is a manifold arrangement of protuberances and indentations. The eye observing from a distance is situated in virtually the same plane as their summits. Hence nobody should be surprised that to the line of sight which grazes them, they appear in an even line without any breaks in it" (Galileo, "Message"; NE III, 69:26—70:16; Carlos, pp. 25–26; Drake, pp. 38–39).

246. Kepler's negative was missed by Bryk (p. 339), who incorrectly made Kepler say that the crevices or bumps "must become visible."

247. Kepler's "interiori" (interior) was mistranslated as "lower" by Bryk (p. 339), who may have misread "interiori" as "inferiori."

248. "Around the body of the moon, as around the earth, there is a sphere of a substance denser than the rest of the aether. The sun's radiation can be received and reflected by this sphere, even though it is not opaque enough (es-

pecially when it is not illumined) to be able to stop our sight from passing through it. . . . It could prevent our sight from reaching the moon's solid body if it had a greater thickness. And in fact it is thicker where the moon curves back. I mean that it is thicker, not absolutely, but relatively to our sight which cuts it obliquely. Therefore it can obstruct our vision and, especially when it is illumined, hide the moon's curvature where that is exposed to the sun. . . . The eye . . . reaches . . . the central region of the moon . . . through vapors . . . that are less thick. But toward the outermost edges the volume of thicker vapors stops our sight from reaching the end. . . . This may perhaps be thought by some people to explain in a reasonable way why the moon's bigger spots are nowhere seen to extend right out to the very edge, although some of them, it may be supposed, are found around the edge too. Nevertheless, the fact that they are not seen appears to be plausibly explained by their being hidden beneath a thicker and brighter volume of vapor" (Galileo, "Message"; NE III, 70:17—71:11; Carlos, pp. 26–28; Drake, pp. 39–40).

249. "Optics," edition of 1604.

250. "The entire moon . . . is surrounded by a certain aerial substance." "I went along with Plutarch to that pitch of audacity where I dared to attribute to the moon continents, seas, mountains, and valleys such as our earth has. How much more courage is required to encircle the moon with air such as girdles our earth? . . . I prefer . . . to ascribe to the moon an atmosphere of no great depth" (GW II, 221:15–16; 261:29–32; 262:6–7).

251. This statement was made by José de Acosta, as Kepler explains in the "Dream," Note 222 (F VIII, 64). In his "Nature of the New World" (Salamanca, 1588), Book II, Chapter 10, Acosta said: "The heat of the burning sun is intercepted by the clouds, and the rains which drop down

from them moisten and cool the air and the earth at the same time" (pp. 83–84 in the Köln 1596 reprint, which was probably the edition used by Kepler).

252. By dittography the 1610 edition (p. 18:20) misprinted "adque ad nos." Frisch cured this misprint by "adque nos" (F II, 498:11–12), in agreement with the letter of April 19 (NE X, 331:419). Hence Hammer's emendation "atque ad nos" (GW IV, 300:6) is unnecessary.

253. The book's title ("Disputation concerning the Manifold Apparent Irregularities, or Regular Non-Uniformities, in the Motions of the Planets in the Heavens, and Their Astronomical Causes") was supplied by Frisch (F II, 498: 14–15), and not by Kepler, as Bryk mistakenly thought (p. 339).

254. Despite Bryk (p. 339), what looked like red-hot iron was not the spot, which was blackish.

255. In 1609 Kepler talked with Mästlin at Tübingen, probably in May or June. Kepler had been granted permission by Rudolph II to travel from Prague to Heidelberg "in connection with the final stages of the production" of his "New Astronomy." The night before Kepler left Prague, his "Singular Phenomenon" arrived from Leipzig, where it was in the printer's shop on April 11. When Kepler reached Heidelberg, he saw that the completion of his "New Astronomy" would take another week. This interval he used to visit his native land. In July he was back again in Prague (GW XVI, no. 526:4; no. 527:3–11; no. 532: 16). Hence his conversation with Mästlin at Tübingen probably took place in May or June.

256. Kepler's "a Th. 88" (from Thesis 88 on) was mistranslated by Bryk (p. 340) as "in Thesis 88." Exactly what Mästlin said "from Thesis 88 on" cannot be quoted because no copy of his book is available any longer. It was already a scarce item in Kepler's own lifetime. An Italian mathematician, who had been recommended to him by

Galileo in 1627, wanted to buy a copy "whatever the price." Having no copy of his own, Kepler appealed to a friend in Tübingen: "Write me . . . whether it survives, and send [me a copy] if you can get hold of one" (GW XVIII, no. 1054; no. 1065:31–35; NE XIII, no. 1836).

In his "Singular Phenomenon" Kepler said: "Two years after the publication of my 'Optics' there appeared a disputation on the irregularities of the heavenly motions, which was presided over by Michael Mästlin, professor of mathematics at Tübingen, while the respondent was Samuel Hafenreffer" (GW IV, 83:23–25). The title page of the disputation announced that "while Michael Mästlin presides . . . on February 21st and 22nd . . . Samuel Hafenreffer of Herrenberg will attempt to defend" the theses propounded in the disputation (GW IV, 489; XV, 541).

When the disputation was printed, Hafenreffer sent Kepler a copy on October 4, 1606 with the following explanation:

> Some time ago, when I approached Professor Mästlin for the purpose of conferring with him, I came across these present theses in his possession. He had written them for his son. I respectfully asked him to hand them over to me so that I could read them. Granting my request, he added a few remarks about the delightfulness of the subject. While diligently reading them and thinking about them, I was stirred so strongly that I persistently asked him to turn them over to me as the topic of a public disputation. In this matter too he did not fail me, and they were sent to the printer. While they were in press, Professor Mästlin became seriously ill and could not perform the painstaking work of correcting the proofs carefully. Therefore typographical errors crept in, which you will be able to rectify. I humbly submit to you a copy of these theses, which I ask you to receive in a spirit of good will (GW XV, 354:14–27).

On November 16, 1606 Kepler acknowledged receipt of the Mästlin-Hafenreffer disputation (GW XV, no. 400: 4–5, 19). Thus he had a copy of it in 1606, shortly after it was printed, but not in 1627, when Galileo's friend asked him for it. When we consider what Kepler lived through in those two intervening decades, we need not be surprised that he lost track of the little disputation.

257. Kepler here refers mainly to Note 141 of his "Dream" (F VIII, 55).

258. Presumably Mästlin found these three passages in the edition of Aristotle's collected works which appeared at Venice in the mid-sixteenth century (reissued, Frankfurt: Minerva, 1962). This edition contained, in Latin translation, not only Aristotle's writings but also the commentaries on them by the twelfth-century Muslim philosopher Ibn Rushd (Averroes). In his remarks on Aristotle's "Generation of Animals," III, 11, Averroes attributed the following proposition to Aristotle: "Since the moon in itself is dark, and is bright on account of another body, it is therefore similar to the earth in nature" (ed. Venice, VII, 233v). In five other passages (V, 16r, 121v, 132v, 137r, 323r; three of these were noticed by Mästlin), Averroes ascribed this statement to Aristotle "in a book on animals." Actually Aristotle did not regard the moon as akin to the earth. In his cosmology the earth was not a heavenly body; it remained motionless at the center of the universe, whereas all the heavenly bodies, including the moon, were in constant motion. How badly Averroes blundered may be seen by comparing what Averroes said Aristotle said with what Aristotle really said. In his "Generation of Animals," IV, 10, Aristotle declared that the moon has something in common with the sun "and becomes as it were a second and lesser sun" (777b 24–26). Yet in his "Epitome of Copernican Astronomy" Kepler repeated the misattribution to Aristotle of the statement, "as quoted by Averroes, that the moon seems to be a sort of aethereal earth" (GW VII, 319:19–21).

259. Kepler's "a Th. 145" (beginning with Thesis 145) was mistranslated as "in Thesis 145" by Bryk (p. 340).

260. Kepler's "limbi" (limb) was overlooked by Bryk (p. 340), who thereby mistakenly made Mästlin attribute transparency to the moon's entire disk, instead of to the limb alone.

261. Kepler's "Multus . . . est" (he devotes much space) was mistranslated as "he seems very great" by Bryk (p. 340).

262. "When this lunar atmosphere is illumined by the sun's rays, it makes the body of the moon look like a bigger sphere." "The part of the moon that is suffused with light seems to belong to a bigger circumference than the rest of the globe which is in shadow" (Galileo, "Message"; NE III, 70:20–22, 71:5–6; Carlos, pp. 26–27, 28; Drake, pp. 39, 40).

263. The 1610 edition (p. 19:8 up) misprinted "quarum," which Frisch and Favaro corrected to "quorum" (F II, 498: 5 up; NE III, 11, n. 1), in agreement with the letter of April 19 (NE X, 331:451).

264. Kepler's "lunae bifidae" (half-moon) was mistranslated as "two-horned moon" by Bryk (p. 340). But in his "Epitome of Copernican Astronomy" Kepler associated the "half-moon" (bifida) with the quadratures, when a straight line from the earth to the sun forms a right angle with a straight line from the earth to the moon, which is cut in half by that straight line (GW VII, 450:12–13).

265. Frisch's reading "etsi" (F II, 498:3 up) is correct, whereas Favaro (NE X, 332:453) and Hammer (GW IV, 301:3) both printed "et si" incorrectly as two separate words. But the ampersand on p. 19:5 up of the 1610 edition of the "Conversation" was joined with "si," not separated from it, as on p. 6:4 up.

266. In the letter of April 19 (NE X, 332:453) Kepler did not specify "lunae," which he inserted in the published

version of the "Conversation" (p. 19:5 up), to make it perfectly clear that he believed in an atmosphere around the moon.

267. Kepler's "ea" (it) refers to the space in the eye that is affected by the lunar region in shadow. This reference was missed by Bryk, who therefore failed to recognize Kepler's contrast between the part of the eye that is affected by the light of the half-moon and of Venus, on the one hand, and the other part of the eye that is affected by the lunar region in shadow. Instead of Kepler's contrast between the two regions, Bryk emerged with only one "tiny bright place adjudged much too big" (p. 340).

268. In the 1604 edition: "We must pay much more careful attention to this peculiarity of vision, because of which all bright things look proportionately bigger to every single person than do adjoining things that are less bright. For in the first or last phase of the moon, the bright horn seems to be bounded by a far bigger circle than is the rest of the body that is illumined by the earth's light and made very clearly visible. The same was true in the lunar eclipse of May 15/25, 1603. For, certain observers were able to perceive the edge of the part in shadow, even though that was more than one-third, and they said that the part in shadow belonged to a smaller circle" (GW II, 194:18–26).

269. Of the Venice, 1610 edition of Galileo's "Message": "It remains for me to talk about the size of the moon's mountains, and to show that the terrestrial cliffs are much smaller than the lunar. I mean that they are smaller, even in the absolute sense, not merely in relation to the dimensions of their globes. This is clearly demonstrated in the following way. I have often observed that, when the moon is in various positions with relation to the sun, some mountain peaks within the part of the moon that is in shadow, even though they are quite distant from the boundary of light [and shadow], seem to be bathed in light. By comparing their distance [from the boundary]

with the entire diameter of the moon, I learned that sometimes this interval exceeds $\frac{1}{20}$ of the diameter. [Such a peak, Galileo goes on to prove] is higher than 4 Italian miles. But on the earth there are no mountains which come close to a perpendicular height of one mile. It is clear, therefore, that the lunar mountains are higher than the terrestrial" (NE III, 71:14—72:13; Carlos, pp. 28–30; Drake, pp. 40–41). Kepler's citation of "page 13" shows that he used the Venice edition of Galileo's "Message," and not the Frankfurt 1610 edition, in which the foregoing passage appears on page 23.

270. Kepler's "passim" in this passage means "casually," not "here and there," despite Bryk (p. 341). For on p. 250 of the 1604 edition of the "Optics" Kepler mentioned the lunar mountains, not here and there, but only once. In the letter of April 19 (NE X, 332:458) Kepler did say that he had mentioned the lunar mountains elsewhere (passim) in his "Optics." But if he was thinking of GW II, 136:15, we can readily understand why he deleted this additional reference from the published version of the "Conversation."

271. The moon's "mountains are bigger in proportion to its globe than are the earth's mountains in proportion to it" (Kepler, "Optics;" GW II, 220:5–6).

272. Of the Venice, 1610 edition of Galileo's "Message": "Choose a position such that a roof or chimney or some other obstruction between the observer and the moon (with the impediment far away from the eye, however) blocks out the moon's shining horns. Nevertheless, the rest of the lunar globe remains visible to our sight" (NE III, 72:34—73:1; Carlos, p. 31; Drake, p. 42).

273. Page 252 of the 1604 edition of Kepler's "Optics" marks the beginning of Chapter 6, Number 10, in which the following passage relating to earthshine occurs on pages 254–255: "The true cause [of this light on the moon that

does not come directly from the sun] was first discovered, so far as I know, by my teacher, Mästlin. He taught it to me and to everybody in his lecture-room 12 years ago, and in 1596 he explained it publicly in Theses 21, 22, and 23 of his 'Disputation on Eclipses.' This principle should be expounded in no other words than those of the author himself. This is what he says [with Kepler's comments in parentheses]:

> In the crescent phase of the moon light is seen not only on the horns, but spread out over the entire body. This light, as is evident to observers, is not made imperceptible by the brilliance of daylight. It is not made imperceptible either by the daylight that remains in the evening after sunset before dusk (that is, while the day is still bright) or by the daylight that together with the dawn in the morning precedes sunrise. On the contrary, it is evident that this same light becomes feebler on the other days further removed from new moon. So true is it that around the quadratures, when the half-moon is far above the horizon in the dead of night, either very little or none of this light is observed remaining (and this is seen only by men with very sharp vision). Hence, from the fact that this light is detachable [from the moon] it follows that it is not the moon's own innate light, as is maintained by some people (including Reinhold), but that like the light predominant throughout the month, it is borrowed from another source. If this were not so, it would surely be seen much more clearly in the dead of night than when the air is illumined by daylight. But the source from which this light is directed to the moon is shown by its position with relation to the earth. For the moon, when it is new, comes between the sun and the earth. The side of the earth which is illumined by the sun lies directly below the moon and faces it. But we are familiar with the strength and brilliance of the sun's rays when they are reflected by individual parts of the earth one by one.

> In exposed places the rays weaken the keenness of our sight. Their light floods the innermost recesses of buildings, if it is permitted to enter even through a small crack. Will anyone deny that the same thing happens to all the light collected and reflected by the entire earth, together with its waters? I therefore assert that with the brilliant light imparted to it by the sun, the earth flashes rays upon the darkness or night on the body of the moon. The earth does so no less than the moon does so in its turn and in an entirely similar way. When the moon is full, with the rays which it receives from the sun it lights up our nights on earth, and in proportion to the brilliance of those rays, it virtually changes our nights into days. This phenomenon is all the more evident to the extent that the earth's circumference is larger than the moon's, the ratio of the former to the latter being more than 12:1. Therefore, as I said above, these two bodies take turns in intercepting the sun's light for each other. Thus each in turn lights up the other's night. This conclusion is supported by the weakening of that light. For as the moon moves away from the position in which it was new, it begins little by little to turn away from this illuminated half of the earth, and to face the remaining part of the earth more and more obliquely. At the same time the strength of the reflected rays is diminished and weakened. As a result, whatever part of this light is reflected on the half-moon or gibbous moon, by reason of its extensive enfeeblement, can be felt on the earth either very weakly or not at all (GW II, 223:10–224:6).*

274. Kepler's "vel" (or) was mistranslated by "as in the case of" by Bryk (p. 341). Kepler is talking about the light that is visible on the moon when it is new or totally eclipsed: "In Book II of his 'Preliminary Exercises' Tycho Brahe attributes the cause of this light to Venus, which is capable of making the moon shine so clearly. But while the moon is waxing, it always benefits from this light, whereas

that side of it is not always exposed to Venus. Furthermore, Venus is many times higher than the moon. Therefore, even if Venus perhaps contributes its light to illuminating the moon's limb more strongly at times, nevertheless a ray from Venus, being blocked by the interposition of the moon's body, does not penetrate to the middle of the moon's disk, which benefits from this light just as much as the limb does" (GW II, 223:1–7). The supposition rejected by Kepler, therefore, maintained that the moon received light from Venus, not that the moon received light from the sun "as in the case of Venus."

275. The words "than you do" (quam tu) were not included in the letter of April 19 (NE X, 332:470), but for the sake of greater clarity were inserted by Kepler in the published version of the "Conversation" (ed. 1610, p. 20: 18–19).

In the "Optics" Kepler said: "I do not deny that sometimes it happens that from the earth we see the moon as a result of the light cast upon it by the bright heavenly bodies opposite it" (GW II, 223:7–9). Thus Kepler did not altogether exclude the possibility that Venus might impart light to the moon. Galileo, on the other hand, rejected the possibility outright: "The assertion that a light of this kind is imparted by Venus is so childish as to be unworthy of a reply. For who is so ignorant as not to know that at the time of conjunction [between moon and sun] and while the angular distance between them is less than 60°, the part of the moon that is turned away from the sun cannot possibly be seen from Venus?" ("Message"; NE III, 73:30–34; Carlos, p. 34; Drake, p. 43).

276. Of the Venice 1610 edition of Galileo's "Message": "The light which appears on the moon in eclipses is . . . reddish and almost coppery. . . . In addition, it can change its place and move about. For it travels over the moon's face with the result that the part nearer to the boundary of the circle of the earth's shadow always seems brighter, whereas the rest seems darker. From all of this

we conclude without any doubt that this phenomenon occurs because the sun's rays nearby impinge upon a denser region which spherically girdles the moon" (NE III, 73: 20–27; Carlos, p. 33; Drake, p. 43).

277. In the 1604 edition, Kepler's discussion of "The Redness of the Moon in Eclipse" begins on p. 271 (GW II, 237:15).

278. "That redness came from the refraction of the sun's rays in the earth's air" (GW II, 241:6–7).

279. Of the "Optics" in the edition of 1604.

280. Kepler's "et accommodas ea quae fol. 301 adduxi, ad rationem dicendam" (You also enhance the usefulness of what I said on page 301 by way of explaining) was mistranslated by Bryk (p. 341) as "You thereby gain also the clearly formulated explanation." But Bryk's version mistakenly transfers this idea of Kepler's to Galileo who, however, said nothing in his "Message" about total solar eclipses. Bryk would have found it more difficult to make this particular error if he had translated Kepler's "what I said on page 301" instead of omitting those words. Incidentally, Kepler does not praise himself by describing his explanation as "clearly formulated." That piece of self-flattery was gratuitously interpolated by Bryk.

281. "Something of this sort [an extension of sunlight to a transparent belt surrounding the sun], we may believe, can happen around the sun also when the moon is interposed between it [and the earth]. Thus, either the air or even an aether-like substance, which is not altogether immaterial but has some density of its own, is illumined by the sun, and generates a brilliance which takes the place of sunlight when the sun is eclipsed" (GW II, 260:36–40).

282. "What is the material, what is the substance, in which this brilliance of the sun inhered? For when light ema-

nates from its source, it itself cannot be perceived unless it is in a substance. For it comes to a halt nowhere, it impinges nowhere, except in some opaque substance. If you say that the earth's atmosphere provided the substance required for this brilliance, you will be refuted in various ways by the experiences of various localities. . . . The place, the material, in which this brilliance of the sun inhered, embraced the moon closely on all sides, and was not at all low and not at all near . . . the earth at a height of one German mile. . . . If the material which absorbed the sun's brilliance were 20 earth-radii above the earth, it would claim for itself one-third of the distance [from the earth] to the moon (even so, we are already in the aether). . . . The material which absorbed this brilliance of the sun could not have been lower than the moon. . . . Surely it was diffused between the sun and the moon, and therefore it was in the aether" (Kepler, "New Star," Prague and Frankfurt, 1606, pp. 116–118; GW I, 263:15–20; 264:11–15, 39–41; 265:5–7).

283. The word "proposed" (dicta) was included by Kepler in the letter of April 19 (NE X, 332:477). It was not omitted, despite the erroneous indication to that effect in Hammer's list of variant readings (GW IV, 506). The cause proposed by Galileo to explain the coppery color of the moon in eclipse was rejected by Kepler. This rejection must have been overlooked by Galileo when he wrote to the Tuscan Secretary of State on May 7, 1610: "From the Imperial Mathematician I have received a letter, or rather a whole treatise in eight leaves, written in approval of all the particulars contained in my book, without contradicting or doubting a single detail, even the smallest" (NE X, 349:18–22; GW XVI, no. 572:1–5; cf. NE X, 358:24–26; GW XVI, no. 574:5–7). Yet at Note 242 in the "Conversation" Kepler doubted a statement by Galileo, and in the passage following Note 290 Kepler opposed Galileo's erroneous account of irradiation, for which he substituted his own correct explanation (see Note 293, below).

284. "A certain dawn-light is diffused to the neighboring regions of the moon, just as on the earth, both in the morning and in the evening, twilight spreads" (Galileo, "Message"; NE III, 73:28–29; Carlos, p. 33; Drake, p. 43). Kepler's "uti vis" (as you call it) was omitted by Bryk (p. 341). Hence he blundered into imputing Galileo's lunar dawn-light to Kepler, who uses the expression "your dawn-light" in addressing Galileo directly just a few lines below, near the end of Section V. Moreover, Kepler's emphasis on the uneven distribution of this reddish light was completely misunderstood and missed by Bryk.

285. Of the "Optics" in the 1604 edition: "On August 6/16, 1598 near Graz clouds covered the sky around the horizon so that as the moon rose in the darkness, it could not be seen. But when it gained a few degrees of altitude, the clouds parted and about half of its body shone forth very conspicuously on account of the red color. Hence that part would not be deemed to be in eclipse, although the entire moon was in shadow, with half of it barely visible. Being unfamiliar with this redness, I was puzzled, for I could not make up my mind whether the moon was entering the shadow or leaving it. I was very doubtful also about the questions why the bright part was not clearly distinguished from the part in shadow, and why the redness had no boundary, but steadily shrank until it finally terminated in shadow over most of the moon. As I was making these observations, the clouds closed up again. Shortly afterwards, as three-quarters past seven o'clock was sounding in the city, the clouds vanished and all my uncertainty was dispelled. For as the bright horn below rose, the redness disappeared and became just like the shadow, so great was the brilliance of the slender horn illumined by the sun. The redness did not subside uniformly over this horn. For above at the left the redness extended in a very broad band, whereas below at the right it was a narrow strip between the bright horn and the part completely in shadow" (GW II, 240:26—241:1).

286. In his "Message" Galileo said: "I shall discuss this matter at greater length in my book 'On the System of the Universe'" (NE III, 73:30; Carlos, pp. 33–34; Drake, p. 43). When the obstacles to the printing of this work were finally overcome by Galileo, he published it as his famous "Dialogue" of 1632.

287. Of the "Optics" in the 1604 edition: "As concerns only the moon's very faint pallor or ashen color, if the question is, whence does this come to the moon, or does it come from the moon's own light, I shall reply, in agreement with Plutarch, that this minute light is imparted to the moon by the heavenly bodies in the vicinity of the sun or by whatever other bright body is in the sky" (GW II, 242:1–5).

288. Kepler's "minui" (shrink) was mistranslated as "very small" by Bryk (p. 342). Kepler quotes Galileo as saying, however, not that the stars and planets in the telescope look "very small in comparison with the diameter of the moon" (as Bryk would have it), but that the moon is magnified by the telescope much more than the stars and planets are, which therefore shrink in comparison with it: "When the heavenly bodies, including both the fixed stars and the planets, are viewed in the telescope, they do not appear to be magnified in the same proportion as other objects and the moon too. On the contrary, in the case of the stars and planets this magnification seems much smaller. Thus a telescope which could enlarge other objects, for example, a hundred times, would be thought to magnify the stars and planets barely four or five times" (Galileo, "Message"; NE III, 75:18–25; Carlos, p. 38; Drake, pp. 45–46).

289. "When the stars appear at sunset as twilight begins, they look very small, even if they are of the first magnitude. . . . Their irradiation can be shorn away by daylight, and not only by that light, but also by a thin cloud coming between a star and the observer's eye. The same

effect is produced by black veils and colored glasses which, when they are placed in the line of sight and interposed, deprive the stars of their surrounding sparkles" (Galileo, "Message"; NE III, 75:32–34, 76:1–5; Carlos, p. 39; Drake, p. 46).

290. NE III, 75:30–31, 76:6–7; Carlos, pp. 39–40; Drake, p. 46. By "adscititios accidentalesque" (adventitious and accidental) Galileo did not mean "disturbing and weakening," despite Bryk (p. 342).

291. This passage of the "Optics" in the 1604 edition was cited previously by Kepler, and is translated in Note 268, above.

292. In the 1604 edition: "Whichever of these causes must be considered in any particular case, surely it is either on account of the image on the retina, or on account of the impression on the visual spirits, that the spreading out of bright objects occurs. . . . The very process of vision has yielded an absolutely clear demonstration that visual errors frequently occur when bright objects are adjudged excessively large" (GW II, 197:8–18). While Kepler was reading the proofs of his "Optics," he added the following remarks: "The expanses of sky between big stars, and also very small stars, have their own radiation. Nevertheless, the points on the retina to which they radiate are occupied by the width of the stronger radiation of the big stars. Therefore those stars look large and surrounded by rays. But as soon as dawn comes, these rays of the bigger stars are obliterated. For at dawn the sky's radiation to its own place on the retina suppresses the bright star's lateral radiation, which travels around the axis of the cone to a place where it does not belong" (GW II, 375:25–32).

293. Kepler's "licebit tibi porro proprie loqui" (you may hereafter discuss the matter correctly) was mistranslated by Bryk (p. 342) as "you can state forthwith." Bryk's version missed Kepler's implication, however, that in the "Mes-

sage" Galileo fails to understand the phenomenon of irradiation, and "hereafter" (porro), having examined Kepler's "Optics," may "discuss the matter correctly" (proprie loqui).

294. "The difference in appearance between the planets and the fixed stars likewise seems worthy of remark. For the planets present their little globes perfectly round and circular, and look spherical, as though they were so many little moons everywhere bathed in light. The fixed stars, on the other hand, are not seen bounded by a circular periphery but, as though they were so many blazes, shooting out rays on all sides and sparkling vigorously. They seem to have the same appearance when they are viewed in the telescope and by natural vision" (Galileo, "Message"; NE III, 76:11–18; Carlos, p. 40; Drake, p. 47).

295. For Bruno's realization that the stars are suns, see Note 57, above.

296. This question mark was omitted, surely by inadvertence, in the 1610 edition of the "Conversation" (p. 22:8). In GW IV, 302:31, Hammer chose to omit the question mark, instead of following the correct punctuation in the letter of April 19 (NE X, 333:510) and in F II, 500:9. In his "De l'infinito universo et mondi" ("Venice," really London, 1584) Bruno said: "Hence there are innumerable suns, and countless earths which revolve around those suns, just as we see these seven [planets] revolve around this sun which is close to us" ("Dialoghi," p. 436; Singer, "Bruno," p. 304).

297. See Section I, from Note 63 to Note 69.

298. "Below the stars of the sixth magnitude you will see through the telescope so numerous a crowd of other stars undetected by natural vision as to be hard to believe. For you may see more of them than of the other six magnitudes. . . . Their number is almost inconceivable" (Galileo, "Message"; NE III, 76:20–27; Carlos, pp. 40–41; Drake, p. 47).

299. "To the numerous multitude of fixed stars which could be seen up to the present time by natural vision, surely it is a great achievement to add countless others, and to put plainly before the eyes stars never seen before and more than ten times as numerous as those known in antiquity" (Galileo, "Message"; NE III, 59:12–16; Carlos, pp. 7–8; Drake, p. 27). A little more than a thousand stars were identified by ancient astronomers.

300. Page 104 of the "New Star" marks the beginning of Chapter 21 in which Kepler, when dealing with the question "Does the Sphere of the Fixed Stars Extend Out to Infinity?," says:

> Astronomy can teach us with absolute certainty that the region of the fixed stars is bounded on its nether side by an obvious limit. Nor is there any truth in the statement that this lower world with its own sun does not differ at all in aspect from any of the fixed stars, that is, in a comparison of region with region or place.
>
> For let it be one of the assumptions that the fixed stars extend outward to infinity. Nevertheless it is true that in this inmost bosom there is an extraordinary void which is distinguished by an enormous difference of proportion from the distances between the fixed stars. Thus suppose that someone happened to see only this void, without also knowing that eight little bodies revolve within a very narrow orbit around the center of this space, without knowing what they are, what their nature is, or how many there are. Nevertheless, from this void alone, as compared with the surrounding spherical region absolutely stuffed with stars, he would be altogether bound to conclude that this is a special place and indeed the primary bosom of the universe. Let us take, for example, the three stars of the second magnitude in Orion's Belt. Each of them is 81′ away from its neighbor, since it is at least 2′ in diameter. Suppose that they are located in the same spherical surface, of which we are the center. An observer

stationed on one of them will see the other subtended by an angle of about 2¾°. This is more than five suns, arranged in a row and touching one another, would cover for us on earth. Yet of all the fixed stars, these are not the closest to one another, since innumerable smaller ones are interspersed. Therefore if anyone were placed on Orion's Belt and had our sun, the center of the universe, over his head, at first he would see, as it were, a solid ocean of huge stars, apparently touching one another. Then, the higher he raised his eyes, the smaller would be the stars he saw, and the less they would touch one another. Gradually they would be further and further apart. Yet over his head he would see the same stars as we do. But he would see them half the size, and to the same extent closer together than we see them. This is not how the sky looks to us. We see the stars everywhere, of various sizes to be sure, but we also see the sky everywhere uniform for the most part. . . . [My adversaries] thought that, if the infinity of the universe were conceded, they would easily separate two fixed stars, which we on earth believe to be very close to each other, by as great a distance as certainly separates us from the fixed stars. But this is impossible. For suppose that two fixed stars which are equally distant from the center of the movable world can be raised as high as you please. They will move as far away from each other as each of them is now from the center of the movable world, just as my adversaries say. But let them remember that if they raise the fixed stars, at the same time they enlarge this void, which is in the middle of the circular band of the fixed stars. Yet they thoughtlessly took for granted that this void of ours would remain the same while the fixed stars went higher. But suppose, they argue, that of the two aforementioned stars in Orion's Belt, one remains in the sphere below which there can be no star, according to parallax theory, while the other is declared to be infinitely high. Will we in this way make them look just as small

> when each one is observed from the other as they both appear to us now? Will the starless void between the two stars be found equal to the space between us and each of them? . . . Without demolishing my contention, I would readily grant this proposition too, that all the fixed stars are of the same size, those which look big to us being near to us, and those which look small being that much further away. . . . I would grant it, I say, but I would not assert it. For just as the stars differ in brilliance and in color, so it is equally easy to believe that they really differ in size too. . . . If the height of the sphere of fixed stars is infinite, that is, if some stars are infinitely high, in themselves they will also be infinite in size of body. For, imagine a star which seems to subtend a definite angle, say, 4′. The width of such a body is always one-thousandth of its distance, as is absolutely certain from geometry. Therefore, if the distance is infinite, the diameter of the star is one-thousandth part of infinity. But all the fractional parts of the infinite must themselves be infinite. Consequently such a star will be infinite. But at the same time it is also finite, because it has a shape, and every shape is bounded by certain limits, that is, it is limited or limiting. But we gave it a shape when we stated that it could be seen subtending a definite angle. . . . Suppose that you extend space, without any stars, to infinity. Surely wherever you put a star in space, as far as that point the distance is finite, and the circumference drawn through the star is finite (GW I, 253:28—254:17; 254:25–40; 255:9–14; 256:32—257:2; 257:8–10).

301. Kepler's "proderit ad fidem, totum perlegi" (it will conduce to assent, if the whole passage is read) was mistranslated by Bryk (p. 343) as "the reading of the entire passage is recommended after the completion of the whole thing." By "the whole thing" (Ganzen) Bryk evidently meant the "Conversation." He must have thought that Kepler was recommending a thorough perusal of the pas-

sage in the "New Star" after the reader had finished the "Conversation." But Kepler's "totum" refers, not to the whole "Conversation," but to the whole "New Star" passage (locum), which he here forbears to summarize. His recommendation is implicit, not explicit; nor does he suggest when the whole passage should be read.

302. Kepler repeatedly emphasized his weak vision (GW I, 210:37; 221:4–5; IV, 71:33–34; XVII, 20:1; F VII, 75: 9–8 up); see also earlier, Note 88.

303. In the 1610 edition (p. 22:10 up) after "maiusculum," by a misprint, there was a semicolon, which was repeated in GW IV, 303:4, although the correct punctuation appeared in the letter of April 19 (NE X, 333:522) and in F II, 500:21.

304. Kepler's "mille solum" (only 1000) was incorrectly thrown into the plural by Bryk (p. 343: thousands).

305. Kepler's "superabunt" (exceed) was mistranslated as "equal" by Bryk (p. 343).

306. In the letter of April 19 (NE X, 334:534) the words "quanta esset" (how great would it become?) were omitted, presumably by inadvertence, since without them "tota camera ablata" (if the whole room were removed) has no meaning. Bryk (p. 343) failed to translate Kepler's statement that between sunlight and starlight "the difference is practically infinite" (infinito pene intervallo).

307. In the 1610 edition (p. 23:14), followed by F II, 500: 12 up, "bolorum" was misprinted for "colorum" in the letter of April 19 (NE X, 334:538), followed by GW IV, 303:23.

308. In Section VIII, following, from Note 386 to Note 396.

309. Kepler's use of the vague expression "aiunt" (people say) would indicate that he is referring to a statement which he had heard rather than read.

310. Kepler's "religiosum" was equated by Bryk (p. 344) with "monk." But the clergyman in question may well have been the Protestant minister, David Fabricius (1564–1617), an assiduous and keen observer, who started a new branch of astronomy, the study of variable stars. He is the challenger mentioned earlier in Note 180.

311. Denying that "the new star in the Swan" was new, Mästlin wrote to Kepler: "I am not disturbed by the fact that it was not included in the catalogue of the stars in antiquity. This it has in common with very many other stars. . . . There are countless others which to our surprise were omitted by Hipparchus, Ptolemy, and the rest" (GW XV, 133:62–67).

312. "I have observed . . . the substance or material of the Milky Way, which we may inspect . . . with our senses aided by a telescope. . . . For the galaxy is nothing but a mass of countless stars crowded close together. To whatever region of it the telescope is directed, immediately a huge collection of stars is brought into view. Many of them seem quite large and very brilliant, while the multitude of small stars is absolutely innumerable.

Not only is that milky brightness, like a white cloud's, seen in the galaxy, but very many patches of similar color gleam here and there in the aether. If you direct the telescope toward any of them, you will turn up a mass of stars set tightly together. Moreover (and this is more remarkable) the stars heretofore called 'nebulous' by every astronomer are aggregates of small stars bunched together in a marvelous way. While each escapes detection because it is small or very far away from us, the mingling of their rays produces that whiteness" (Galileo, "Message"; NE III, 78:8—79:5; Carlos, pp. 42–43; Drake, pp. 49–50).

313. "According to Democritus, many small contiguous stars illuminate one another, and their light, which is merged on account of their compactness" is the Milky Way (Pseudo-Plutarch, "The Opinions of the Philosophers," III,

1). This work was utilized by Kepler when he was still a student at Tübingen, as we saw earlier in Note 235.

On the other hand, when he was writing his "Defence of Tycho" in 1600, he made extensive use (F I, 270–274) of Macrobius, who said that the Milky Way was, according to "Democritus, countless stars, all small. They are compressed together in a crowded band, the very narrow spaces intervening between them being hidden. Since they are everywhere close to one another, they radiate in all directions. Through this scattering of their rays, they display a continuous body of merged light" ["Commentary on Scipio's Dream," I, 15; English translation by William H. Stahl (New York: Columbia Univ. Press, 1952), p. 149].

314. "The whole vast celestial world supplies abundant material, in my judgment, for the formation of an additional star, yet nowhere more plentifully and more fully than near the Milky Way. . . . This new star achieved solidity at the very edge of the galaxy. . . . Comets also . . . for the most part are formed and arise near the regions of the galaxy. . . . These heavenly bodies likewise . . . have a very close kinship with the Milky Way, so that most of them too may not unreasonably be thought to take their origin thence" (Brahe, "Preliminary Exercises," Part III, Conclusion; TB III, 305:14–16, 20; 306:34–42).

As recently as in his "New Star" of 1606 Kepler said: "Great applause greeted Brahe's . . . opinion that the [new] star of that year [1572] . . . was compacted from the material of the Milky Way." For himself, Kepler evaluated as "most excellent" the "opinion expressed by Brahe that such stars are created out of the Milky Way." Yet, after considering two objections, Kepler concluded: "Therefore I rather incline to the view that the heavens everywhere are suitable for supplying the material for these bodies" (GW I, 251:9–12; 258:4–5; 259:5–6). It is evident, therefore, that Galileo's "Message" weaned Kepler away from his former belief in the creation of new stars and comets out of the Milky Way or some other such celestial "material."

315. In Section I, above, from Note 43 to Note 57.

316. In the letter of April 19 (NE X, 334:555) Kepler wrote "made victorious" (vincere). This expression, he must have realized on second thought, was much too strong, and therefore he replaced it by "to some extent restored to life" (nonnihil recreari) in the published version of the "Conversation" (ed. 1610, p. 24:6).

317. In the letter of April 19 (NE X, 334:556) Kepler jokingly said that the chains and prison would have been prepared "by Wackher," but he deleted his friend's name in the published version of the "Conversation" (ed. 1610, p. 24:8).

318. The words "for the present," and Kepler's related admission that the "fear gripped me as soon as I had heard about your book from my opponent's triumphal shout," were not included in the letter of April 19 (NE X, 334: 558), but were inserted in the published version of the "Conversation" (ed. 1610, p. 24:10–11).

319. The words "once more" (de novo) were not included in the letter of April 19 (NE X, 334:560), but were inserted by Kepler in the published version of the "Conversation" (ed. 1610, p. 24:14–15).

320. By mistranslating Kepler's "horridae" (dreadful) as "powerful" (gewaltigen, p. 345), Bryk reversed Kepler's attitude toward Bruno's philosophy. This was not admired by Kepler as "powerful," but despised as "dreadful."

321. Kepler would have found it difficult to specify which characteristics of the Arctic Zone had been disclosed by Greek theoretical astronomy before Pytheas sailed from his native Marseille to northwest Europe shortly before 300 B.C. The impact of Pytheas' voyage on Greek theoretical science, as distinguished from descriptive geography, was

recently discussed by David Reginald Dicks, "The Geographical Fragments of Hipparchus" (Univ. of London: Athlone Press, 1960), pp. 24–25, 29, 165–166, 179–192.

322. Julius Caesar, "Gallic War," V, 13, 4: "By precise measurements with water we saw that the nights are shorter than on the continent."

323. Kepler's "Belgarum in septentrione hiemationem" (the Dutchmen's spending the winter in the north) was mistranslated by Bryk (p. 345) as "spending the winter in the north of Holland." Kepler is talking about the Dutch Arctic explorers who were forced to spend the winter on Novaya Zemlya while they were searching for a northeast water passage around Europe to China. Kepler's knowledge of this expedition was derived from Gerrit de Veer's "Nautical Diary" (Amsterdam, 1598), a copy of which was sent to him by a friend on May 24, 1599 (GW XIII, 338: 24). The English translation (London, 1609) of De Veer was reprinted by the Hakluyt Society (1st ed., 1853; 2nd ed., 1876).

324. The fabulous island Atlantis was described by Plato in his "Timaeus," 24E–25D, and in his "Critias," 108E, 113C–121C.

325. Plutarch's "Moon" does not mention Thule. Nevertheless Kepler ("Dream," text at Note 2, and Note 174) so identified Plutarch's island "whose distance from Britain is a run of five days as you sail toward the west" (941A). Farther west, on another of Plutarch's imaginary islands (941F) a god "is confined in a deep cave, asleep on a rock shining with gold," as Kepler translated the passage (F VIII, 99:12–11 up).

326. "In after years an age will come
When ocean will unhook the chains,
And earth to its full size extend;
The waters will reveal new worlds,

And Thule will no longer be
Land's end"
(Seneca, "Medea," 375–379).

327. Kepler's "Argonaut from Florence" is Vespucci, not Columbus (despite Hammer, GW IV, 510). The dedication of Vespucci's "Four Voyages" (as translated into Latin in Martin Waldseemüller's "Introduction to Cosmography," St.-Dié, 1507) made it clear that Vespucci was of Florentine origin, and stated: "We discovered much continental land and almost innumerable islands, most of them inhabited. These were not mentioned by our ancestors. Hence the ancients had no knowledge of them, I believe."

328. In Columbus' authentic writings available to Kepler there is no indication that the discoverer of America "divined the New World from the direction of the winds" or, for that matter, ever realized what he had really discovered. Was Kepler perhaps thinking of some travel report, a type of literature which flourished in that great age of exploration, and which Kepler devoured avidly?

329. "There are five solid figures, which are also called the mathematical figures. From the cube, says Pythagoras, the earth arose; from the pyramid, fire; from the octahedron, air; from the icosahedron, water; from the dodecahedron, the sphere of the universe" (Pseudo-Plutarch, "The Opinions of the Philosophers," II, 6). Thus, on this view, the four elements and the universe arose out of the five regular solids without being arranged by any god. Kepler utilized Pseudo-Plutarch's "Opinions," as we saw earlier in Note 235. Hence there is no need to conjecture (as Thorndike does, "History of Magic," VII, 13) that Kepler read the foregoing passage in a medieval commentary. Moreover, to associate the traditional four elements plus the universe with the five regular solids is a very different conception from Kepler's use of the five solids as the boundaries of

the six planetary orbits. This idea occurred to Kepler in a purely astronomical context, according to his own published statement (GW I, 11:35—13:23; cf. XIII, 28:39–45). Why, then, at this late date should its origin be found in subconscious suggestion by a passage which Kepler may never have seen?

330. "Timaeus," 55D–56B.

331. In the "Elements," Book XIII deals with the five regular solids, which do not serve as models for the arrangement of the world by any god.

332. In the letter of April 19 (NE X, 335:579) Kepler originally said "virtually" (quasi), which he then changed to "only" (non nisi). But in the published version of the "Conversation" he went back again to "quasi" (ed. 1610, p. 25:10).

333. Kepler claims to have risen from the merely factual outlook of Copernicus to causal explanation. But he does not claim a further ascent from natural causes to the teleological purposes of the Creation, despite Bryk (p. 346).

334. Kepler is excessively generous when he includes Copernicus in this statement. Actually Copernicus did not share Kepler's unique view regarding the relation of the five regular solids to the six planetary orbits.

335. In the letter of April 19 (NE X, 335:595) Kepler said "prove to be false" (falsitatis convincis). But he softened this expression to "unsettle" (dubiam reddis) in the published version of the "Conversation" (ed. 1610, p. 25:2 up).

336. Kepler's "mutuatam" (borrowed) was omitted by Bryk (p. 346). He thereby unjustifiably changed Bruce's status as a mere follower of Bruno to a thinker of equal rank with that gifted Italian.

337. "Each one of them [the fixed stars] is a sun, in a world no smaller than this planetary world of ours" (Bruce's letter to Kepler; GW XIV, 450:17–18). For Bruno's view, see Note 57.

338. "The heavenly bodies, except the planets, . . . are all suns or fiery," and the planets are "watery worlds." Beneath a fire there "always lies a humid substance, and this cannot subsist firmly of its own strength unless dry matter and heat are associated with it." "The worlds are composed of contraries, some of which, like the earths, these being waters, live and grow by means of the other contraries, like the suns and fires" (Bruno, "De immenso," IV, 8, 9; "Opera latine conscripta," I, Part 2, pp. 45, 46, 48; "De l'infinito," "Dialoghi," pp. 464–465; Singer, p. 324).

339. In the letter of April 19 (NE X, 335:601) Kepler said: "the emptiness of all his reasoning" (totam illius rationem esse de nihilo). But he deleted the "all," and also softened his adverse judgment to "the weakness of his reasoning" (illius rationem infirmam esse) in the published version of the "Conversation" (ed. 1610, p. 26:6–7).

340. These persons evidently caused Kepler to moderate his original rejection of Bruno's idea. For he inserted the two preceding sentences in the published version of the "Conversation" (ed. 1610, p. 26:9–12), whereas their absence in the letter of April 19 (NE X, 335:601) indicates that Kepler then discounted the possibility that planets would ever be discovered rotating around any star.

341. The last five words were not included in the letter of April 19 (NE X, 335:603), but were inserted in the published version of the "Conversation" (ed. 1610, p. 26:12–13).

342. Kepler's unqualified acceptance of Galileo's discovery completely refutes the unfounded allegation that in the "Conversation" "he expresses his doubts, especially about the actual existence of the satellites of Jupiter" [Giorgio

Abetti, "Amici e nemici di Galileo" (Milan, 1945), p. 65; Abetti, "Keplero" (Brescia, 1951), p. 63].

343. This sentence was not included in the letter of April 19 (NE X, 335:603), but was inserted in the published version of the "Conversation" (ed. 1610, p. 26:14).

344. This statement was mistakenly transferred from Kepler to Galileo by Bryk (p. 347). Galileo did not attribute inhabitants to the moon and to Jupiter, despite Bryk.

345. In the letter of April 19 (NE X, 336:606) Kepler said instead: "at Wackher's dinner table" (in mensa nostri Vackherii).

346. In Vespucci's "Four Voyages" the first two crossings were calm and safe. Perhaps Kepler did not read as far as the third voyage ("On those days [of the Atlantic crossing] we experienced worse weather than anyone had ever suffered at sea before") and the fourth voyage ("A fierce and bitter storm arose, and a contrary wind and adverse weather prevailed"); in Waldseemüller, "Introduction to Cosmography," fol. e2v, f3v.

347. See Note 24.

348. "According to Alcmaeon and the mathematicians, the planets move from west to east, as opposed to the fixed stars" (Pseudo-Plutarch, "The Opinions of the Philosophers," II, 16, 2). Because this report refrains from saying that Alcmaeon was the first to distinguish between the planets and the fixed stars, Kepler may have chosen to refer to a deliberately undefined period before this distinction was clearly drawn.

349. Pythagoras was the "first to say that the evening star and the morning star are the same, as Parmenides declares"; Parmenides "is thought to have been the first to detect the identity of the evening star and the morning star . . . but some say it was Pythagoras" (Diogenes Laertius, VIII, 14; IX, 23).

350. "Moses has been thought by almost everybody to be the author of the Pentateuch," Spinoza remarked in his "Theologico-Political Treatise," Chapter 8 (Hamburg, 1670). This magnificent plea for freedom of thought and expression was published (anonymously, for reasons of prudence) forty years too late for Kepler to profit from its overpowering arguments against Moses' authorship of the first five books of the Hebrew Bible.

351. In Job 38:32 Venus was equated with the Hebrew word "Mazzaroth" by Giovanni Virginio Schiaparelli, "Astronomy in the Old Testament" (Oxford, 1905), pp. 48, 74–85, 166–175. But with regard to "Mazzaroth" Victor E. Reichert, "Job" (London: Soncino, 1960), p. 202, stated: "While the derivation and significance of the word are unknown, it is clear from the context that a star or group of stars is intended. Some authorities regard it as another form of 'Mazzaloth' (rendered 'constellations') in 2 Kings 23:5, which is thought to indicate the signs of the zodiac." Hence Kepler was right in saying that the planets are not mentioned in Job.

352. Why did Kepler single out these three parts of the Hebrew Bible as not mentioning the planets? These bodies are not mentioned anywhere else in the Hebrew Bible, with the possible exception of Isaiah 14:12, where "Day Star, son of the morning" may be Venus. In Amos 5:26 some overzealous interpreters have professed to see an oblique reference to Saturn.

353. The four satellites of Jupiter discovered by Galileo, he reported in his "Message," "revolve in unequal circles. This deduction is clearly drawn from the fact that at the greater distances from Jupiter no two satellites could ever be seen in conjunction. On the other hand, near Jupiter two, three, and sometimes all of them were observed crowded together at the same time. Moreover, the revolutions of the satellites describing the narrower circles around Jupiter are inferred to be swifter. For the satellites closer

to Jupiter are often seen east [of the primary planet] the day after they appeared west of it, and contrariwise. But the satellite which traverses the largest circle seems to complete its orbit in half a month, if you carefully examine its movements as recorded previously" (Galileo, "Message"; NE III, 94:30—95:8; Carlos, pp. 68–69; Drake, p. 57).

354. "What is an aspect? It is an angle formed at the earth by the luminous rays of two planets which is effective in stimulating a sublunar being" (Kepler, "Epitome of Copernican Astronomy"; GW VII, 479:10–12).

355. "On the second day [of February, 1610] . . . Jupiter was 6′ away from the nearer satellite on the west, and this in turn was 8′ away from the satellite further west" (Galileo, "Message"; NE III, 87:17, 25–27; Carlos, pp. 56–57; omitted by Drake).

356. The apparent diameter of the sun or moon is approximately ½°; $2 \times 14' = 28' < ½°$.

357. Astrology was bitterly attacked and fiercely defended in Kepler's time. His attitude in this controversy is perhaps best illustrated by his resolve "to refute some things in astrology, to confirm some things, to improve some things" ("Third Man in the Middle," Thesis 41; GW IV, 185:9–10). In particular, he wrote, "This kind of thing, namely, the aspect of two celestial bodies, both of them or either being movable, is virtually the only feature which in my judgment should be retained in astrology. This feature I vigorously defend against the philosophers, who are thoroughly ignorant of the art, by means of philosophy and the theory of harmony (which is almost completely unknown [to them]). With equal confidence I maintain that almost all the rest of the astrologers' stuff must be thrown away, and I so declare incessantly in all my astrological writings" (GW I, 166:40—167:5).

358. In the Dedication of his "Message" Galileo publicly announced his acceptance of Copernicanism by stating that

the four newly discovered satellites "with motions differing among themselves . . . complete their revolutions around Jupiter . . . with wonderful swiftness, while in the meantime all of them with unanimous accord also perform enormous revolutions simultaneously every twelve years around the center of the universe, that is, the sun" (NE III, 56:12–16; Carlos, pp. 3–4; Drake, p. 24). For a later passage in the "Message" in which Galileo did not hesitate to mention Copernicus' name, see Note 384.

Kepler publicly announced his acceptance of Copernicanism in his "Cosmographic Mystery" of 1596. Nevertheless it is not true that "the first voice on the continent raised publicly in favor of the Copernican theory was Johannes Kepler's," despite Arthur Koestler, "Kepler and the Psychology of Discovery," in "The Logic of Personal Knowledge, Essays Presented to Michael Polanyi" (Glencoe: Free Press, 1961), p. 49. For in his "De Immenso," which was published at Frankfurt in 1591 while Kepler was still a student at Tübingen, Giordano Bruno included an enthusiastic eulogy of Copernicus together with lengthy extracts from the "Revolutions" ("Opera latine conscripta," I, Part 1, pp. 380–385). Immediately after his poetic paean in praise of Copernicus, Bruno exclaimed: "It is wonderful, O Copernicus, that you were able to emerge from the immense darkness of our age, when the entire light of philosophy lies extinguished, as well as the light of the other subjects which depend on it." Kepler's familiarity with Bruno's "De immenso," which was written in Latin, is made evident in the text of the "Conversation" at Notes 57, 338, and 402.

359. Kepler's "orbis magni" (great circle) was a technical term in Copernican astronomy (Rosen, "Three Copernican Treatises," pp. 16–17). This technical term was not recognized by Bryk (p. 349), who attached "magni," not to "orbis," but to "diametri." However, in that case Kepler would have had to write "magnae," not "magni" (as in "diameter virtuosa," GW III, 253:15); besides, how can

any one diameter of a circle be singled out as "large"? In his "Epitome of Copernican Astronomy" Kepler wrote the following question and answer: "In Copernicus' astronomy what is the 'great circle' (orbis magnus)? This is what Copernicus calls the earth's true orbit around the sun. . . . He calls it 'great,' not on account of its size, since the circular orbits of the outer planets are much larger, but on account of its extraordinary usefulness in explaining the apparent motions not only of the sun but also of all the primary planets" (GW VII, 403:4–9).

360. According to Ptolemy, the sun's distance from the earth was 1210 earth-radii, and the moon's mean distance from the earth was 59 earth-radii ("Syntaxis," V, 15; English translation in "Great Books," XVI, 175). Ptolemy's numerical results were rounded off as 1200 and 60, giving a ratio of $1/20$.

361. "For me, the sun climbed to a height of 1800 earth-radii. . . . I liked the round number 1800, so that it would be about 30 times the distance earth-moon" (Kepler, "Ephemerides," p. 2, no. 7:11–14; F VII, 483:8–10). In his "Epitome of Copernican Astronomy" Kepler further increased the distance earth-sun to $3469\frac{1}{3}$ earth-radii (GW VII, 279:3–5). This would make the ratio of the solar (that is, terrestrial) and lunar orbits nearly 60:1. Actually it is almost 400:1.

362. With the distance earth-sun = 20, the diameter of the moon's path = 1 subtends at the sun an angle 2α such that $\tan \alpha = \frac{1}{2} \div 20 = 1/40 = 0.025$. Therefore $\alpha \cong 1°30'$, and $2\alpha \cong 3°$.

363. Now $\tan \alpha = \frac{1}{2} \div 30 = 1/60 = 0.0133$. Therefore $\alpha \cong 1°$ and $2\alpha \cong 2°$.

364. Setting the distance earth-sun = 1000, Kepler put Saturn's mean distance at 9163 (GW I, 74:26). In round numbers, therefore, Saturn was 10 times more remote from the sun than the earth was, a ratio not far from the actual.

365. In the same table Jupiter's mean distance from the sun was 5261 or, in round numbers, 5 times the earth's distance (GW I, 74:29). In his "Epitome of Copernican Astronomy" Kepler said: "Saturn's distance is shown by Copernican proofs to be slightly less than ten times the earth's distance from the sun, and Jupiter's distance, five times" (GW VII, 267:2–3). Actually Jupiter is slightly more than 5 times more distant from the sun than the earth is.

366. Not "from the sun," despite Bryk (p. 349).

367. $3^\circ = 180' \div 10 = 18'$.

368. $2^\circ = 120' \div 10 = 12'$.

369. $3^\circ = 180' \div 5 = 36'$.

370. $2^\circ = 120' \div 5 = 24'$.

371. In the letter of April 19 (NE X, 337:662) Kepler did not include "incolis" (inhabitants), which he inserted in the published version of the "Conversation" (ed. 1610, p. 28:5 up) in order to make it perfectly clear that he believed both Saturn and Jupiter to be inhabited.

372. In the letter of April 19 (NE X, 337:663) Kepler used the expression "planetarum Iovialium," but in the published version of the "Conversation" (ed. 1610, p. 28:5 up) Kepler substituted "planetarum circum-Iovialium," in order to make it perfectly clear that the satellites revolve around Jupiter.

373. Tan $\alpha = 1/_{1200} = 0.00083 \cong 3'$. In Ptolemy's table of solar parallax, the maximum (at the horizon) is $2'51''$ ("Syntaxis," V, 18; ed. Heiberg, I, 443:50; English translation, "Great Books," XVI, 182). "What is the horizontal parallax of the sun or moon. . . ? Horizontal parallax is the angle subtended at the sun or moon by two lines, one of which is tangent to the surface of the earth, and the other is drawn through its center" (Kepler, "Epitome of Copernican Astronomy"; GW VII, 490:4–6).

374. In 1605 Kepler wrote to a correspondent: "I keep barely 1′ for the parallaxes of the sun" (GW XV, 263:922). Later on, in his "Epitome of Copernican Astronomy" Kepler expressed himself more precisely: "The solar parallax is 59″, or less than 1′, when the earth is at its farthest distance from the sun; but when the earth is at its closest to the sun, the solar parallax is an equal amount more than 1′" (GW VII, 490:20–21). Actually, the sun's mean equatorial horizontal parallax is somewhat less than 9″.

375. $2 \times 3' = 6'$.

376. Kepler's "sesqui" (1½) was mistranslated by Bryk (p. 349) as "bigger by a half." But that would make the moon 9′. However, Kepler put the earth:moon volume ratio = $4/1$ ("Dream," Note 206), and $1.5' \times 4 = 6'$.

377. $1' = 60'' \div 10 = 6''$.

378. $1' = 60'' \div 5 = 12''$.

379. Kepler's "vastitatis illorum globorum" (the hugeness of those globes) was mistranslated as "those desolate spheres of the universe floating away" by Bryk (p. 350), who evidently mistook "vastitatis" (vastness) for "vastatis" (devastated). Was Brahe's inference from the size of Jupiter to its being inhabited conveyed by word of mouth to Kepler, or is it waiting to be dug out of the fifteen volumes of TB?

380. Jupiter's axial rotation was not detected by Galileo, nor was it reported in his "Message." This phenomenon was inferred more than half a century before it was actually observed. However, this brilliant speculative inference was attributed by Kepler to Wackher, not to himself, despite Robert Grant, "History of Physical Astronomy" (London, 1852), p. 244: "The illustrious Kepler, previous to the invention of the telescope, had surmised that Jupiter revolves on an axis." Wackher's surmise was put forward after, not previous to, the invention of the telescope. To

Wackher's surmise, Kepler added the further inference (GW IV, 343:38–39) that the period of Jupiter's rotation is less than one day; actually it is about ten hours. Even more astounding is Kepler's guess (GW XVI, 357:9, 11–12) about a Red Spot on Jupiter, a phenomenon which first attracted the special attention of astronomers nearly three centuries later.

381. Kepler, "New Astronomy"; GW III, 245:9–16; translated earlier in Note 205.

382. "This force which takes hold of the planetary bodies and transports them is an incorporeal emanation from the force which is located in the sun." "The force which extends out from the sun to the planets moves them in a circle around the immovable body of the sun." "Around the stationary center or axis [of the sun] its parts move from place to place (in the same space, however, since the [sun's] entire body is stationary)." "We may believe that in the sun there is no force attracting the planets, as in a magnet (for they would continue to approach the sun until they were completely joined to it), but only a directional force. Hence the sun has circular fibers which sweep around in the direction shown by the zodiac. Therefore the perpetual rotation of the sun is accompanied by the circular rotation of that moving force or outflow of the emanation from the sun's magnetic fibers. This outflow is diffused throughout all the planetary distances, and its rotation occurs in the same period as the sun's" (Kepler, "New Astronomy"; GW III, 240:20–22; 242:19–20; 243:4–6; 246:8–16).*

383. "Everything embraced by the moon, and the earth's center, revolve in an annual circuit around the sun along that great circle amidst the other planets." "The annual revolution occupies the place in which we said the earth is contained together with the lunar sphere as an epicycle" (Copernicus, "Revolutions"; ed. Zeller, II, 24:24–26; 26:2–3; English translation in "Great Books," XVI, 525).

384. "We have an excellent and perspicuous argument to remove the doubt of those who calmly accept the revolution of the planets around the sun in the Copernican system, yet are so troubled by the motion of a single moon around the earth while both bodies in the meantime execute an annual orbit around the sun that in their judgment this blueprint of the universe must be destroyed as impossible. Now we have not just one planet rotating around another, while both traverse a great circle around the sun. On the contrary, our senses show us four satellites travelling around Jupiter, like the moon around the earth, while all four, together with Jupiter, complete a great circle around the sun in a period of twelve years" (NE III, 95: 8–18; Carlos, pp. 69–70; Drake, p. 57).

385. This question mark was present in the letter of April 19 (NE X, 337:681), but it was omitted, presumably by inadvertence, in the 1610 edition of the "Conversation" (p. 29:12 up), which was uncritically followed by Frisch (F II, 503:4 up) and Hammer (GW IV, 307:31).

386. In Section VI, near Note 301.

387. In Section VI, from Note 301 to Note 308.

388. Kepler's "expressit" (elicited) was mistranslated as "expressed" by Bryk (p. 351). But how could Wackher express the thought and still "seem by his silence to assent" to it? This expression (silentioque consentire visus est) was substituted by Kepler in the published version of the "Conversation" (ed. 1610, p. 30:11) for "he agreed with it and praised it" (assensuque laudavit) in the letter of April 19 (NE X, 338:697).

389. Kepler's "a globo" (after the sphere) was mistranslated as "derivable from the sphere" by Bryk (p. 351). But the five regular solids are not derived from the sphere. In his "Cosmographic Mystery" Kepler quoted Euclid's description of the five regular solids as "formed by equilateral and equiangular planes equal to one another." "Of the solid

figures, therefore, the regular bodies come nearest to the perfection of the sphere" (GW I, 27:38–39; 28:11–12, 31–32).

390. Yet in Section I, Kepler described Bruno's infinite worlds as similar; see Note 69.

391. "The infinite exists, both by addition and by subtraction" (or "by division," according to an alternative reading; Aristotle, "Physics," 206a 15–16).

392. "In number, as you move in the direction of the smallest, there is a limit" (Aristotle, "Physics," 207b 2).

393. In the "New Star" Kepler put the sun's distance from Saturn = 14,320 earth-radii, and from the stars = 34,077, 066⅔ (GW I, 235:13–24). These figures, which Kepler deduced by reasoning about the mathematical proportions which the universe must exhibit, yield a ratio of about 1/2300. But he used 1/3000 as a convenient approximation (GW I, 237:12–13).

394. See Note 364, above.

395. This word was inadvertently omitted in the letter of April 19 (NE X, 338:714). But in closing the gap Kepler evidently did not take the time to look back at his much more accurate calculation in the "New Star": "How small, I ask, is man as compared with the globe of the earth. Let's compute. From the [earth's] surface to its center there are 860 miles, each being 5,000 paces. Hence there are 4,300,000 paces. Multiply by 5, to convert to feet, and the result is 21,500,000. Let a man be exactly 7 feet tall, and divide that number by these 7 feet. Hence, if you put 3,100,000 men in a row of equal length, it will stretch from the earth's surface to its center. And one diameter of the earth will equal more than the height of 6,000,000 men" (GW I, 237:2–9).

396. The man who first saw and described microscopic organisms was born two years after Kepler died.

397. Kepler's expression "the sun of righteousness" is an echo of Malachi 4:2. But there "the sun of righteousness" is an instrument of the Hebrew God, and is not equated with the divinity, as it is here by Kepler for his own theologico-astronomical purposes.

398. Matthew 24:29 ("the powers of the heavens"); Mark 13:25 ("the powers that are in the heavens").

399. "Thus it is apparent that it was not proper for man, the inhabitant of this universe and its destined observer, to live in its inwards as though he were in a sealed room. Under those conditions he would never have succeeded in contemplating the heavenly bodies, which are so remote. On the contrary, by the annual revolution of the earth, his homestead, he is whirled about and transported in this most ample edifice, so that he can examine and with utmost accuracy measure the individual members of the house. Something of the same sort is imitated by the art of geometry in measuring inaccessible objects. For unless the surveyor moves from one location to another, and takes his bearings at both places, he cannot achieve the desired measurement" (Kepler, "Optics"; GW II, 277:21–29).

400. This parenthesis was mistranslated by Bryk (p. 352) as "For the sake of equality, the earth is distinguished from the other primary planets by the secondary satellites and the moon's sphere."

401. Kepler's "tornatum" (rotates) was mistranslated as "stationary" by Bryk (p. 352). But, according to Kepler, it was by its rotation that the sun instigated all the planetary motions.

402. "De immenso"; "Opera latine conscripta," I, 1, 216:4; 260:16; 262:8 up; I, 2, 49:9 up.

403. Kepler calls the rhombic dodecahedron "cuboctahedral" because the diagonals of its 12 faces are the edges of the cube and the octahedron. For a like reason, he calls the rhombic triacontahedron "icosidodecahedral" because the

diagonals of its 30 faces are the edges of the icosahedron and the dodecahedron. On November 12/22, 1599, Kepler informed Mästlin: "I am trying to deduce the eccentricities [of the planetary orbits] from the rhombic solids of 12 and 30 planes, as well as from the Archimedean" (semi-regular solids; GW XIV, 87:21–22). Then in his "New Year's Gift" Kepler recalled: "I began a geometrical investigation to see whether there can be constructed from rhombs alone a body similar to the five regular solids and Archimedes' fourteen [semi-regular solids]. I found two [rhombic solids]. One of them is related to the cube and the octahedron; and the other, to the dodecahedron and the icosahedron (for the cube itself, being related to two pyramids fitted to each other, takes the place of the third [rhombic solid]). The first one is enclosed by 12 rhombs, and the second one by 30" (GW IV, 266:11–16). Later on, in his "Harmonics," Kepler gave the number of Archimedean semi-regular solids correctly as 13, not 14 (GW VI, 84:12). In that same context (GW VI, 83–84) he discussed at greater length the two rhombic solids which he had discovered. A method of constructing these two solids out of cardboard is described by H. Martyn Cundy and A. P. Rollett, "Mathematical Models," 2nd ed. (Oxford: Clarendon, 1961), pp. 120–122. The statement by Harold S. M. Coxeter, "Regular Polytopes," 2nd ed. (New York: Macmillan, 1963), p. 31, that "the rhombic dodecahedron and triacontahedron were discovered by Kepler about 1619" is wrong by 20 years, as is shown by Kepler's letter of 1599 to Mästlin, quoted above.*

404. In Section I, at Note 50; and in Section VIII, at Notes 333, 334, 389, and 402.

405. In Section I, at Note 47.

406. Kepler's "serio" was translated correctly by Bryk (p. 354). But then, without any warrant in Kepler's Latin, Bryk interpolated "later." Did he perhaps translate "serio" a second time, this time confusing it with "sero"? Actually,

Kepler's serious or earnest investigation of the moon's place in his arrangement of the five solids was reported, not later, but in his first major publication, the "Cosmographic Mystery," Chapter 16 (GW I, 55–57; 74:34–36).

407. Galileo did not find any more satellites. Nor has any later astronomer found any moons of Venus. Two satellites of Mars have been discovered.

408. "Finally, I must not omit the reason why it happens that the Medicean planets . . . are sometimes seen more than twice as large" (as at other times; Galileo, "Message"; NE III, 95:18–21; Carlos, p. 70; Drake, p. 57).

409. "We certainly cannot look for the explanation in the vapors of the earth, since the satellites seem bigger or smaller while Jupiter and the nearby fixed stars show no change of size. Do the satellites approach the earth and withdraw from it, around the perigee or apogee of their revolutions, to such an extent as to provide the explanation of so great a change? This idea appears altogether unacceptable, since motion along a narrow circle cannot produce this result at all. On the other hand, motion along an oval (which in this case would be virtually a straight line) seems untenable and absolutely inconsistent with the phenomena" (Galileo, "Message"; NE III, 95:21–29; Carlos, p. 70; Drake, pp. 57–58).

410. "It does not seem in the least out of the question to put around Jupiter an atmosphere denser than the rest of the aether. . . . Because this atmosphere intervenes, the satellites look smaller when they are at their furthest from the earth. On the other hand, when they are at their closest to the earth, they look bigger because this same atmosphere vanishes or becomes thinner" (Galileo, "Message"; NE III, 96:3–8; Carlos, pp. 71–72; Drake, p. 58, turned Galileo's explanation into a senseless jumble, in which Jupiter's atmosphere is both present and absent at the perigee of the satellites).

411. Kepler's thought was grossly misunderstood by the author of an attack on Galileo's "Message." Kepler wrote a powerful counterattack on August 9, 1610 in the form of a private letter to Galileo, which he offered to let Galileo publish if he deemed it in his own interest to do so (GW XVI, 323:142–143; NE X, 417:128–129). From the (now lost) original draft of that counterattack Kepler had omitted a section, which he reinstated about two months later in a letter to Giuliano de' Medici: Galileo's opponent "thinks that I applied the term 'plane of the disk' to what in other contexts is called 'the lens that is on the outside and directed toward the stars.' He is, as you see, utterly mistaken. I had made disks out of your new planets, not out of pieces of glass. It was the plane of those planets (not the plane of the glass) that I had said was tilted toward Jupiter. Thus, my words 'lighted perpendicularly above and below,' are applied by that slightly deaf individual to a piece of glass, which has two surfaces, an upper and a lower, whereas I speak of the planets being illumined when they revolve above and below Jupiter. And what illumines was interpreted by him as Jupiter illuminating the glass, whereas in my sense it was the sun illuminating the planets. Thus the various colors, the various planes, are all applied by him to the glass, whereas I applied them to the planets" (GW XVI, 341:21–31; NE X, 463:17–25).

412. Actually, the four satellites discovered by Galileo lie very nearly in the plane of Jupiter's equator. However, six of the satellites discovered by later astronomers are steeply inclined to their primary's equatorial plane.

413. Modern astronomers are disposed to attribute the satellites' varying brightness to the shifting pattern of illuminated areas and dusky markings on their surfaces as different parts of these surfaces are presented to the observer.

414. This Postscript was not included in the letter of April 19 (NE X, 340), but was written shortly thereafter for

inclusion in the published version of the "Conversation" (ed. 1610, p. 35).

415. Hence the catalogue of the spring book fair at Frankfurt in 1610 (*Catalogus universalis pro nundinis francofurtensibus vernalibus de anno 1610*) reached Prague on April 20.

416. "A New Consideration of Archimedes' little treatise 'On the Measurement of the Circle,' in which (1) Archimedes' calculation is refuted; (2) a more accurate calculation shows that the ratio between the circumference of a circle and its diameter is greater than $3^{1\frac{1}{2}/7}$; (3) the true squaring of the circle, proved geometrically, is included" (Dortmund, 1609; *Catalogus,* fol. D1v). Behind "Gephyrander," the author's grecized surname, may have stood Brückmann or Brückner. Since he described himself on the title page as "Salliceto Westphalo," presumably he was from Weidenau in Westphalia. Kepler's reaction to the announcement of the book was later confirmed by a mathematical friend, who considered the book itself an act of "unfortunate and ridiculous presumptuousness" (GW XVII, 226:79). Two historians of mathematics took the trouble to analyze the basic defect in the book's professed quadrature of the circle: Abraham Gotthelf Kästner, "Geschichte der Mathematik" (Göttingen, 1796–1800), III, 55–57, and Jean-Etienne Montucla, "Histoire des mathématiques," 2nd ed. (Paris, 1799–1802; reissued, Paris: Blanchard, 1960), IV, 625. But the most extensive examination of Gephyrander's errors was made by Philip Colbin, professor of mathematics at Würzburg University, whose unpublished manuscript was summarized by Kaspar Schott, "Magia universalis naturae et artis" (Würzburg, 1657–1659), III, 632, 756–757, 762–778.

417. "Mercury, which points out to those who cling to [the fast, winged horse] Pegasus' back the way through the stars to the stars; as a supplement, the astrological discovery of 30°, never observed heretofore in predictions of

the weather and of the changeable lower region of the air, as well as some other subjects" (Montbéliard, 1610; Leipzig *Catalogus,* fol. C4r; Frankfurt *Catalogus,* fol. C2v). Five years earlier Sattler (1579–1610) had published in the same city an "Astrological Investigation which inquires into the true causes of all astrological predictions, but examines and condemns the false causes; by way of tailpiece, Aristotle is defended against the host of newcomers who have written about the appearance of the stars just discovered in recent years; finally, as a supplement, a succinct explanation of astrology, being the true system of astrological definitions and distinctions" (4°, 22 + 392 pages, index). Sattler published also a short tract on the comet of 1607. In issuing his "Astrological and Meteorological Prediction" at Basel for 1608, he indicated that he belonged to that branch of the Sattler family which was called Wyssenburg or Weissenburg. In September 1609, for his degree as Doctor of Law, he upheld "Theses on the Rights and Privileges of Doctors," which was posthumously printed at Basel in 1618. He had previously received two other degrees from the University of Basel: B.A. in 1597, and Ph.D. in 1600 ["Die Matrikel der Universität Basel" (Basel, 1951–1962), II, 434].

418. Kepler's "significatum" was mistranslated by Bryk (p. 355) as meaning that astrologers recognized 30° as an effective aspect. But Sattler (mistakenly) believed that his book was going to introduce the 30° aspect to astrologers.

419. Despite what Kepler says, the 30° aspect was not mentioned in Mästlin's 1606 theses, according to the statement made by Hammer when he had access to a copy of this elusive disputation (GW IV, 510).

420. Is "1603" a slip of the pen for "1607"? The five traditional aspects were increased by Kepler to eight: "The ancients accepted no more than five (aspects, as they are commonly called): conjunction, opposition, quadrature, trine, and sextile. But at first reasoning taught me to add

three others: quintile, double quintile, and sesqui-quadrature. These were confirmed afterwards by wide experience" (Kepler, "The More Reliable Foundations of Astrology," written in the latter part of 1601; GW IV, 22: 21–25). As late as the "New Star" (1606) Kepler specifically excluded 30°: "I accept eight of the aspects, if conjunction is included: sextile, quintile, quadrature, trine, double quintile, sesqui-quadrature, and opposition. Therefore, even though $\frac{1}{12}$th or 30° is a simple fraction of a circle, still it is not an aspect" (GW I, 190:39—191:1). This had been Kepler's attitude a decade earlier in the first edition (1596) of his "Cosmographic Mystery": "We have the reason . . . why planets at a distance of one . . . sign from each other are not considered to be in aspect. For, as we saw, nature recognizes no such harmony in voices" (GW I, 42:27–29). But in the second edition (1621) of his "Cosmographic Mystery" Kepler wrote in a note: "I was wrong in omitting the semi-sextile or 30°" (F I, 146: ee, l. 2). His change of attitude toward the semi-sextile was indicated in a private letter: "The non-traditional aspects, that is, the quintile, double quintile, and sesqui-quadrate, I regard as adequately established by meteorological experience. But the same experience not infrequently gives support also to the semi-sextile or $\frac{1}{12}$th of a circle" (GW XVI, 85:36–39). Kepler wrote this letter on November 30, 1607.

421. By entitling this treatise "Tertius interveniens," Kepler indicated that he was taking an intermediate position between two disputants as the "Third Man in the Middle," not "the Third Coming," despite Burke-Gaffney, "Kepler and the Jesuits," p. 79.

422. Leipzig *Catalogus,* fol. F4r; Frankfurt *Catalogus,* fol. E3r.

423. In the "Third Man in the Middle" Kepler said: "Visual and manifest experience put the semi-sextile aspect in my

hands"; "I strongly emphasize the semi-sextile" (aspect; GW IV, 205:13–14, 19).

424. "It has often been observed that a sublunar being is stimulated also by the semi-sextile aspect, which intercepts one-twelfth of a circle." "Why . . . is the semi-sextile, which plays no part in music, not only included but also emphasized among the foremost aspects? The reason is that the aspects are formed, not by music, but by geometry" (Kepler, "Harmonics"; GW VI, 258:14–15; 261:19–22). The foregoing passage was evidently formulated nearly a decade before Kepler published the "Harmonics" in 1619.

ADDITIONAL NOTES

26. In the "Conversation" Kepler called Galileo a "gentleman of Florence" (Patricio Florentino; GW IV, 288:3, 290:20). When Galileo, who had been born in Pisa, went to Florence, he did not "return to his native Florence," as in I. Bernard Cohen, "The Birth of a New Physics" (Garden City: Doubleday, 1960), p. 84 (cf. p. 66).

42. Toward the end of the "Conversation's" Notice to the Reader, it will be recalled, Kepler said: "I do not think that Galileo, an Italian, has treated me, a German, so well that in return I must flatter him." Presumably Kepler was chiding Galileo for refusing to transmit his reaction to the "Cosmographic Mystery." In the aforementioned letter of August 4, 1597, Galileo said: "Thus far I have seen only the Preface of the book," and he promised Kepler: "I shall read your book through and through

patiently" (GW XIII, 130: 6–7, 14; NE X, 68:8, 15–16). Did Galileo keep his promise? "In 1597 . . . Galileo read Kepler's 'Cosmographic Mystery,'" says Alfred Rupert Hall, "From Galileo to Newton, 1630–1720" = "The Rise of Modern Science," Vol. 3 (New York: Harper & Row, 1963), p. 43. Is there any evidence that Galileo actually read Kepler's "Cosmographic Mystery"?

44. In fact, it was the forthright depiction of Wackher as departing from scholastic tradition that provoked the second of the three objections to the "Conversation" that are enumerated by Kepler in the Notice to the Reader.

85. Although Kepler was thanked by Galileo for having complete faith in his assertions, we are told that "It has often been regretted that two contemporary astronomers of such outstanding genius as Kepler and Galileo should have been so indifferent to one another's achievements" [Herbert Dingle, "Astronomy in the Sixteenth and Seventeenth Centuries," in "Science, Medicine, and History, Essays . . . in Honour of Charles Singer" (Oxford Univ. Press, 1953), Vol. 1, p. 463].

93. The happiness felt by the emperor while observing the moon did not last very much longer, since shortly after the publication of the "Conversation," Rudolph II, the "ruler of Christendom," as he was dutifully designated by his Imperial Mathematician, Kepler, was compelled by his subjects to abdicate.

122. In Galileo's telescope the lenses were "both flat on one side, while on the other side one of them was spherically convex and the other concave" (Galileo, "Message"; NE III, 60: 34–35; Carlos, p. 10; Drake, p. 29). Hence it is not true that Galileo "used a bi-convex object-glass and an eyepiece which was bi-concave," as in Colin A. Ronan, "Changing Views of the Universe" (New York: Macmillan, 1961), p. 125.

273. Since earthshine was discussed by Mästlin in his "Disputation on Eclipses" of 1596, and by Kepler in his "Optics" of 1604, Galileo's account of the phenomenon in his "Message" of 1610 should not be labeled a "startling discovery," as in Cohen, "Birth of a New Physics," p. 75.

382. Although the motions of the planets are not in fact caused by the "sun's magnetic fibers," Kepler's theory has an historical importance, which was discussed by Edward Rosen, "The Debt of Classical Physics to Renaissance Astronomers, particularly Kepler," in the *Proc. Tenth Intern. Congr. Hist. Sci.* (Paris: Hermann, 1964), pp. 84–85.

403. Kepler did not explain how he made this discovery. But the course of his reasoning was plausibly retraced in the German translation of his "Strena" or "New Year's Gift" by Fritz Rossman, assisted by Max Caspar and Fritz Neuhart, "Johannes Kepler, Neujahrsgabe" (Berlin: Keiper, 1943), p. 48.

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